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November 3, 1993

Mr. William F. Caton
Acting Secretary
Office of the Secretary
Federal Communications Commission
1919 M Street
Washington, D.C. 20554

Dear Sir:

I have enclosed with this letter a signed original and four copies of comments on MM Docket 93-225.

Cordially,

Encl

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	MM Docket No. 93-225
	)	
Amendment of Part 73 of the Commission's Rules to Clarify the Definition and Measurement of Aural Modulation Limits in the Broadcast Services	)	

In my 20+ years of broadcast engineering experience, mostly in FM radio, no issue so critical to a station's success has been as difficult to define and control as modulation. Many colleagues have been forced to change jobs because they were unable to satisfy both station management and their personal responsibility to the Rules.

I respectfully submit the following comments regarding Aural Modulation Limits, reflecting this experience. To illuminate the problem from a broadcast engineer's point of view, I will relate the history of audio processing and modulation in FM broadcast service, comment on modulation measurement methods, provide data on occupied bandwidth of FM stations in the San Francisco market, and summarize the results of experiments I performed regarding modulation levels and occupied bandwidth.

History

Major Edwin Howard Armstrong, the "Man of High Fidelity," developed and promoted FM as a high quality broadcast medium for the public. For many years FM stations operated with little or no audio processing. In fact, the biggest problem then was to maintain the minimum modulation requirements in the Rules.

By the mid 1960's most FM stations had a broadband Automatic Gain Control (AGC) amplifier followed by a pre-emphasized peak limiter. A good example is the CBS Laboratories "Audimax" AGC and "Volumax" limiter. This allowed for consistent modulation without constant human supervision.

As FM stations' audiences grew, program directors came over from AM stations where high modulation levels were desired to overcome the inherent noise problems of AM radio (which prompted Major Armstrong to invent FM in the first place). They brought with them the perceived value of being "the loudest station on the dial." Engineers, pressured to increase average modulation levels to make the station "louder", were forced to compromise fidelity by increasing the amount of pre-emphasized limiting to the point where the station sounded "dull", or to violate the modulation limits. Dolby Laboratories proposed "Dolby FM", based upon their Dolby "B" design, which would allow a listener to restore the high frequencies through standardized limiting and expansion. Before this idea could achieve any market share, new technology bypassed it.

In the early 1970's, two products were introduced which would completely change the nature of FM modulation. The first was Bob Orban's Optimod 8000. This device integrated modulation control and the stereo generator, completely eliminating modulation overshoots due to non-linear group delay in the necessary band pass filters in stereo generators. The Optimod 8000 was louder, brighter, and cleaner than any system previously used by FM stations.

The second device was Mike Dorrough's Discriminate Audio Processor, the "DAP." This device was the first manufactured system that split the audio into different bands (the "DAP" had three) so that the time constants of the limiters could be optimized for each audio band. (Previously some very clever engineers assembled their own multiband processing from off-the-shelf equalizers and limiters. These were kept secret, generally in a locked rack.) The net result was much greater audio density or RMS power which, in turn, allowed stations to be "loud" with fewer audible artifacts.

The next fifteen years saw continuous processing hardware advances as different manufacturers developed "new and improved" audio processing that all promised to be "louder" and "cleaner". The point has arrived where no further improvement in loudness can be made without serious audible discomfort to listeners, and today's processing, if desired, can easily be offensive with essentially no dynamic range.

Audio processing technology has moved beyond analog to Digital Signal Processing (DSP), which allows processing topologies impossible to achieve in the analog domain.

While audio processing evolved, FM stations found their highly processed audio still lighting the modulation peak flashers in their type-accepted monitors. Station engineers either appeared to violate FCC rules, or spent uncomfortable moments in the station general manager's office explaining why the station was not as "loud" as the competition. Part of the problem was due to the high density audio causing a slight DC baseline shift in the modulation monitor's AC coupled amplifiers; part was caused by off-air reception impairments (i.e., multipath) in modulation monitors at the studios to comply with the Rules; and part was due to less than perfect time-domain response in composite Studio-Transmitter Link (STL) systems, especially first and second generation composite STL's.

One heavy-handed solution was a composite clipper. This didn't solve the modulation monitor problem, but did solve the composite STL peak problem by clipping off the peaks. Carefully used, a composite clipper was acceptable, but when program directors decided "More is Better", the amount of clipping was increased to the point of substantial clipping at all times. This created havoc in the baseband spectrum and caused the phenomenon of "pilot modulation." The story goes that one program director bragged that his station's stereo pilot light "flashed in time with the music."

The more egregious cases of composite clipping were found to be dropping the pilot below the minimum 8% and were cited by the FCC, but improved clippers were developed that reinserted pilot. What toned down the use of composite clippers was increased demand for (and cash flow available from) subcarrier services. Any amount of composite clipping makes subcarrier users suffer.

The modulation monitor problem was solved by eliminating the requirement for monitors. Stations no longer had to have one, so they no longer had to watch the flashers. Smart engineers moved their monitors to the transmitter so they could minimize the errors due to poor reception. Stations were no longer limited to type approved monitors, so modifications were available to improve the dynamic response of the audio metering circuitry. The need for accurate modulation metering has never been eliminated; stations are still required to keep their modulation to accurate limits, and most modulation monitors are still in service.

It is interesting that during the period when the Rules required stations to use modulation monitors, the FCC used a different -- not type approved and thus unacceptable to licensees -- method of measuring modulation. This discrepancy is mentioned in the NOI (part 8.), and led me to propose the system in this Response as a simple method of accurately determining FM modulation.

Modulation Discussion

Some things simply can not be defined precisely enough to allow for effective regulations. Two that are germane are (1) Loudness and (2) Peaks of Frequent Recurrence.

The Commission has been down the loudness road before, and I have worked with this problem throughout my career. Simply put, no electronic method of determining loudness will correspond to human hearing because program content is the dominant factor in loudness perception.

For example, to some people, rock and roll is too loud no matter at what level it is played.

I agree with the comments on loudness in the NOI and only mention this because relative loudness is a major competitive issue to broadcasters.

The second area that I believe can not be defined precisely enough for regulation is Peaks of Frequent Recurrence.

The NOI raises the question of the definition of overmodulation. Existing rules do not specify any limit on "peaks of frequent recurrence" other than a station can not have them. Much time has been spent debating the relative merits of the vague limits of "less than 10 per minute" or "peaks of less than 1 millisecond". Does a listener's perception of a station's loudness change when there is nine, ten, or eleven peaks per minute? If a peak of less than 1 millisecond can be ignored, will a listener hear the difference if peaks less than 10 milliseconds can be ignored? Or less than 100 microseconds? Is a very short peak at 1,000% more or less of a problem than a longer one at 110%?

Furthermore, how much of this problem is actually on the air and how much of it comes from inaccurate measurement methods? I believe that it is mostly measurement inaccuracies and prefer to improve accuracy. My proposal is based on the method used by the FCC for field enforcement and this will eliminate the discrepancies between different methods (FOB practice vs. formerly type accepted modulation monitors).

Proposal

Both the FCC Field Operations Bureau and I measure FM modulation by calibrating an oscilloscope connected to the wideband output of an FM demodulator, using the second Bessell null of an audio frequency at 13,586 Hz as the standard. This precisely defines 75 kHz deviation of an FM carrier. Modulation is then read off of the oscilloscope screen.

Doing this over a wide range of frequencies requires a good FM signal generator, a good FM tunable demodulator, and a spectrum analyzer in addition to the oscilloscope and audio generator. However, any FM station has a good FM signal generator on their carrier frequency (their exciter), and my proposed system eliminates the need for demodulator, spectrum analyzer, and oscilloscope.

It is a two-part measurement system, shown as Figure 1. Part one is a high level single conversion superheterodyne receiver with a narrow band pass IF filter, followed by an envelope detector and meter. This displays carrier level around the selected RF frequency and substitutes for the spectrum analyzer. The Carrier Level meter needs an approximate logarithmic scale to show carrier nulls, but it does not have to be very accurate. This receiver can also have a wideband FM demodulator to drive standard stereo demodulation and metering.

The other part has a stable, crystal controlled, low distortion 13,586 Hz sine wave generator which can be switched to the composite input of the station's exciter. Bridged across the output to the exciter is a precision DC coupled peak meter with either a LED or other electronic display (not a mechanical meter movement). The Modulation Meter would have display increments of 1% or less between 90% and 125%, and hold peak levels long enough for the human eye to perceive them. It also can have enhancements, such as an alarm above a preset point.

To use the system, the switch is moved from Normal to Calibrate. The 13,586 Hz Set control is adjusted so that the second carrier null is displayed on the Carrier Level meter. The Modulation Calibrate control is then adjusted so that the Modulation Meter displays exactly 100% modulation. The switch is then moved back to Normal.

At this point, the Modulation Meter is calibrated exactly for the exciter in use and the meter displays exact modulation with no errors due to imperfect RF response or multipath. Modulation readings can be consistently and easily determined to 1%, which is far greater than any other system that I am aware of, allowing for a station to operate exactly to the limit specified by the FCC in the Rules. This eliminates the Peaks of Frequent Recurrence problem; modern processing coupled with accurate metering does not need the extra tolerances that this issue is based upon. Calibration to 125% will allow stations with subcarriers to determine their modulation accurately (e.g., for 10% subcarrier injection their modulation limit is now 105%.)

My proposed system has some disadvantages: (1) it must be used at the exciter, (2) it is limited to one exciter (although a station can calibrate a second exciter to the first if necessary), and (3) it requires a short amount of time (about one minute) with tone on the air for calibration. Since the final adjustments for modulation are at the exciter anyway and, once set, modern exciters drift very little, the calibration only needs to be done at irregular and infrequent intervals. I do not believe that the disadvantages are overwhelming.

Modulation Conclusion

I believe that with accurate metering, the Rules do not need a "fudge factor". I strongly recommend eliminating the "Peaks of Frequent Recurrence" from the Rules and requiring all stations to hold to the 100% modulation limit. The commission acknowledges in the NOI that "stations which overmodulate tend to do so in an egregious manner which is apparent from any measurement method used."

I do not see eliminating Peaks of Frequent Recurrence as a hardship for a station. Should station management decide on minimal processing they can back off the average modulation to give themselves plenty of margin for error. Even a first generation Orban 8000 Optimod, for example, has very accurate peak modulation control. On the other hand, if a station determines that it is in their best interests to operate at the very edge of maximum modulation, then they can use whatever device(s) that they feel are necessary to operate at, but not over, their modulation limit.

If a station determines that their existing measurement devices are inaccurate, they must upgrade their equipment's accuracy or reduce their modulation until they are confident that they are not exceeding the maximum modulation limit.

This is one area where competition in the marketplace will benefit the industry, as the most cost-effective accurate systems will win out over others.

Occupied Bandwidth

The NOI raised a question regarding occupied bandwidth. Unlike Standard AM stations, the occupied bandwidth of a wideband FM system is a complicated non-linear function. The occupied bandwidth can be calculated for a single sine wave, but the calculations quickly become very difficult as the complexity of the modulation baseband increases. While my mathematical skills are not what they were in my college days, it appears to me that predicting occupied bandwidth in real time based upon baseband content will require far too much computer power to be cost effective.

However, it is not difficult to measure actual occupied bandwidth of real FM radio stations. I have in my home laboratory a system capable of accurately measuring most parameters of most FM stations in the San Francisco area. The receiving antenna has line-of-sight to all three major transmitter locations (Mt. Beacon, Mt. Sutro, and Mt. San Bruno) and I can receive 17 stations with little multipath. I measured total modulation and occupied bandwidth on those stations. (Other stations in the area that can not be received well are not included.) The results are summarized in Table 1 and shown in Appendix 1-1 through 1-17. To keep my friends and colleagues from organizing a lynch mob, the stations are in no particular order and are referred only to as Station 1 through Station 17.

My system is shown in Figure 2. It uses a Radio-Shack 20-013 Discone Antenna, mounted about 20 feet AGL, fed through RG-214/U coax to an Icom IC-R7000 receiver. The receiver's 10.7 MHz IF output can either feed a Tektronix 2710 Spectrum Analyzer or a modified TFT 723 FM Frequency and Modulation Monitor (modified to bypass its RF front end and accept RF input at its IF frequency).

The demodulated baseband feeds a TFT 724 Stereo Monitor, a Tektronix 2445 Oscilloscope and, if desired, the Tektronix 2710 Spectrum Analyzer. The Oscilloscope is calibrated to 100% modulation at 75 kHz deviation with a 13,586 Hz second Bessell null.

A swept spectrum analyzer such as the Tektronix 2710 can not display wideband FM occupied bandwidth accurately in any one sweep, as the size and number of sidebands changes as the analyzer sweeps through the channel, but the maximum occupied bandwidth can be measured by using an analyzer such as the 2710 with digital display storage and processing and a Peak Hold mode. When this mode is entered, the display will start to "fill out" and eventually no longer changes as the maximum occupied bandwidth reaches a limit. In most cases this happens in just a few minutes, but for consistency each measurement was made over a period of 10 minutes, similar to the measurement requirement in 73.44(a) for AM stations. The analyzer was set for bandwidth measurement 25 dB below carrier and it automatically moved the markers until it found the bandwidth at the 25 kHz bandwidth breakpoint in 73.317(b). Modulation was measured by moving calibrated cursors in the Tektronix 2445 Oscilloscope so that the peaks just touched the lines.

Most stations were operating at, or slightly above, the maximum modulation point. The first nine stations were not operating with subcarriers and were very close to the 25 dB bandwidth limit of 240 kHz. The next four stations had one or more subcarriers but were also within the 25 dB bandwidth limit. The last four stations exceeded the bandwidth limit significantly. Three of them had very wideband subcarriers, which I understand to be data services. Station 17 appeared to have two standard analog subcarriers approximately 6 dB above the 19 kHz pilot or approximately 20% injection each.

All of the stations are within the 600 kHz bandwidth limitation of 35 dB below carrier. System noise floor prevented measuring all of the way down to 80 dB below the carrier.

It would appear that stations using wideband data subcarriers exceed the occupied bandwidth limit of 73.317(b), while stations without subcarriers and stations with reasonable (and legal) subcarriers injection comply with the occupied bandwidth limits.

Occupied Bandwidth vs. Modulation Experiment

In light of the above, I devised an experiment to relate baseband complexity and modulation levels with occupied bandwidth. After some attempts, I assembled the equipment as shown in Figure 3. Though not state-of-the-art or identical to the subcarrier generators used today, it provides a reasonable representation of complex baseband without taking a station off the air for experiments or obtaining special subcarrier generators.

The experimental system uses a Bext TEX-20 Exciter (turned down to less than 1 Watt output through a total of 40 dB of attenuation) to feed the measurement system in Figure 2. The Bext TEX-20 could be fed by either a 13,586 Hz sine wave synthesizer of my own design to calibrate the system, or fed with a Moseley SCG-3T Stereo Generator (about 1970 vintage) and/or a "data subcarrier" generator comprised of a B&K 3030 Sweep/Function Generator, FM modulated by a white noise generator that was shaped by rolling off the high frequencies at approximately 6 kHz. The frequency domain signature of this generator approximated the shape of the data subcarriers measured off the air.

The stereo generator could be fed in L+R (mono), L-R, Left Only and Right Only modes with a pink noise generator. While measurements were made in all of the possible modes (excepting Right Only, as it has the same occupied bandwidth as Left Only) I felt the "worst case" bandwidth approximating normal FM broadcasting was Left Only. L-R had higher occupied bandwidth, but very few stations broadcast in 100% L-R (at least intentionally). Left Only modulation was set to -1, 0, +1, +2 and +3dB relative to 100% modulation, with a constant 10% "data" subcarrier modulation and occupied bandwidth was measured for each case.

The results of these experiments are summarized in Table 2 and shown in Appendix 2-1 through 2-11.

It would appear that Left Only modulation slightly exceeds the 25 dB limit of 240 kHz. Since very few stations transmit programming completely on a single channel, this result agrees well with actual field data. Left - Right modulation does exceed the limit, but it would be very rare to find this in real life, as a station with perfect L-R has no monaural compatibility. The series of measurements made with Left Only and the "Data" subcarrier shows that the "station" begins to exceed the occupied bandwidth limit at 90 % total modulation, and greatly exceeds the limit above 100% modulation.

More careful bandwidth shaping of the "Data" subcarrier would slightly reduce the occupied bandwidth. There is a need for more careful research in this area, as both my experiments and off air measurements indicate that there is a conflict between the Rules and some subcarrier uses.

A pragmatic solution would be to increase the occupied bandwidth allowed at 25 dB below the carrier to approximately 300 kHz, as the stations seem to be operating without interference to adjacent stations.

Conclusions

In summary, I respectfully offer the following conclusions:

1. Eliminate the "fudge factor" of Peaks of Frequent Recurrence and require all FM stations to operate with modulation not exceeding the maximum allowed for their operation.

2. Encourage innovative measurement methods to improve modulation measurement accuracy. There is no need to return to type acceptance.

3. It would appear that the bandwidth limitations of 73.317(b) may need review. If FM stations are actually using approximately 300 kHz occupied bandwidth without interference then it may be best to change the limit to 300 kHz at 25 dB below the carrier. The other limits may not need revising.

Respectfully submitted,

William F. Ruck, Jr., NCE
PG-12-7920

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San Francisco, CA 94122

Table 1

Off-Air Measurements

San Francisco FM Stations

Station Number	Percent Modulation	Occupied Bandwidth	Subcarriers
1	108%	232 kHz	None
2	105%	248 kHz	None
3	95%	210 kHz	None
4	98%	240 kHz	None
5	100%	220 kHz	None
6	101%	220 kHz	None
7	99%	242 kHz	None
8	105%	240 kHz	None
9	103%	238 kHz	None
10	107%	222 kHz	57 kHz and 92 kHz
11	102%	230 kHz	67 kHz
12	101%	240 kHz	57 kHz and 72 kHz
13	112%	240 kHz	67 kHz and 92 kHz
14	109%	294 kHz	67 kHz Wideband Data
15	121%	278 kHz	67 kHz Wideband Data
16	118%	264 kHz	90 kHz Wideband Data
17	116%	316 kHz	67 kHz and 92 kHz

Table 2

Laboratory Experiments

Experiment Number	Description	Percent Modulation	Occupied Bandwidth
1	Mono	100%	238 kHz
2	Stereo Pilot Only	9%	70 kHz
3	Left + Right	100%	234 kHz
4	Left - Right	100%	267 kHz
5	Left Only	100%	250 kHz
6	"Data" Only, No Pilot	10%	192 kHz
7	"Data" and Pilot	20%	204 kHz
8	"Data" and L-R	100%	292 kHz
9	"Data" and L+R	100%	240 kHz
10	"Data" and Left Only	100%	268 kHz
11	"Data" and Left Only	70% / -3 dB	212 kHz
12	"Data" and Left Only	80% / -2 dB	228 kHz
13	"Data" and Left Only	90% / -1 dB	248 kHz
14	"Data" and Left Only	110% / +1 dB	280 kHz
15	"Data" and Left Only	125% / +2 dB	332 kHz
16	"Data" and Left Only	140% / +3 dB	340 kHz

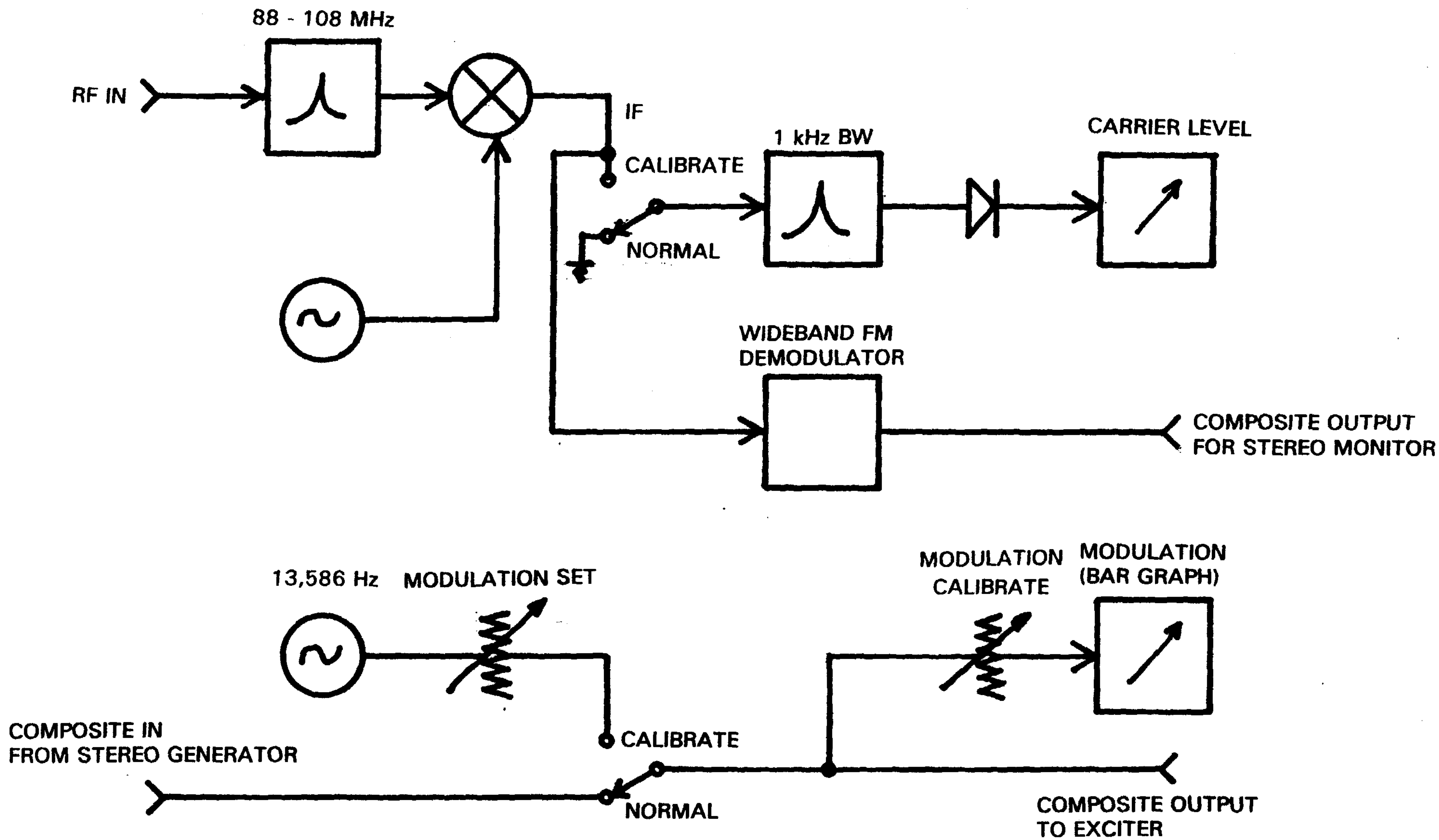


FIGURE 1 Modulation Monitor / Calibrator

Response to NOI 93-225
Wiliam F. Ruck, Jr.   Broadcast Engineer

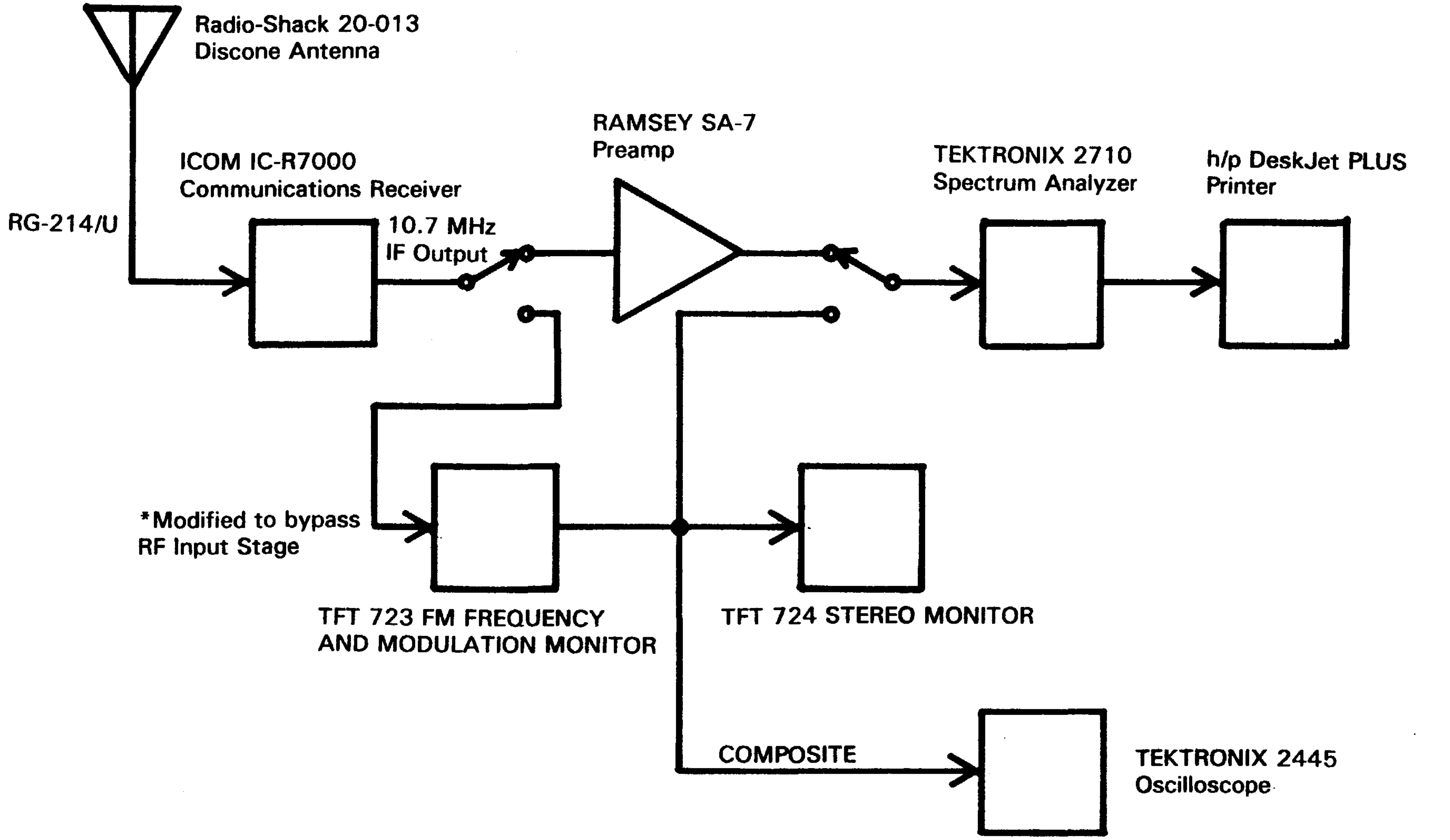


FIGURE 2 MONITORING SYSTEM

Response to NOI 93-225
William F. Ruck, Jr. Broadcast Engineer

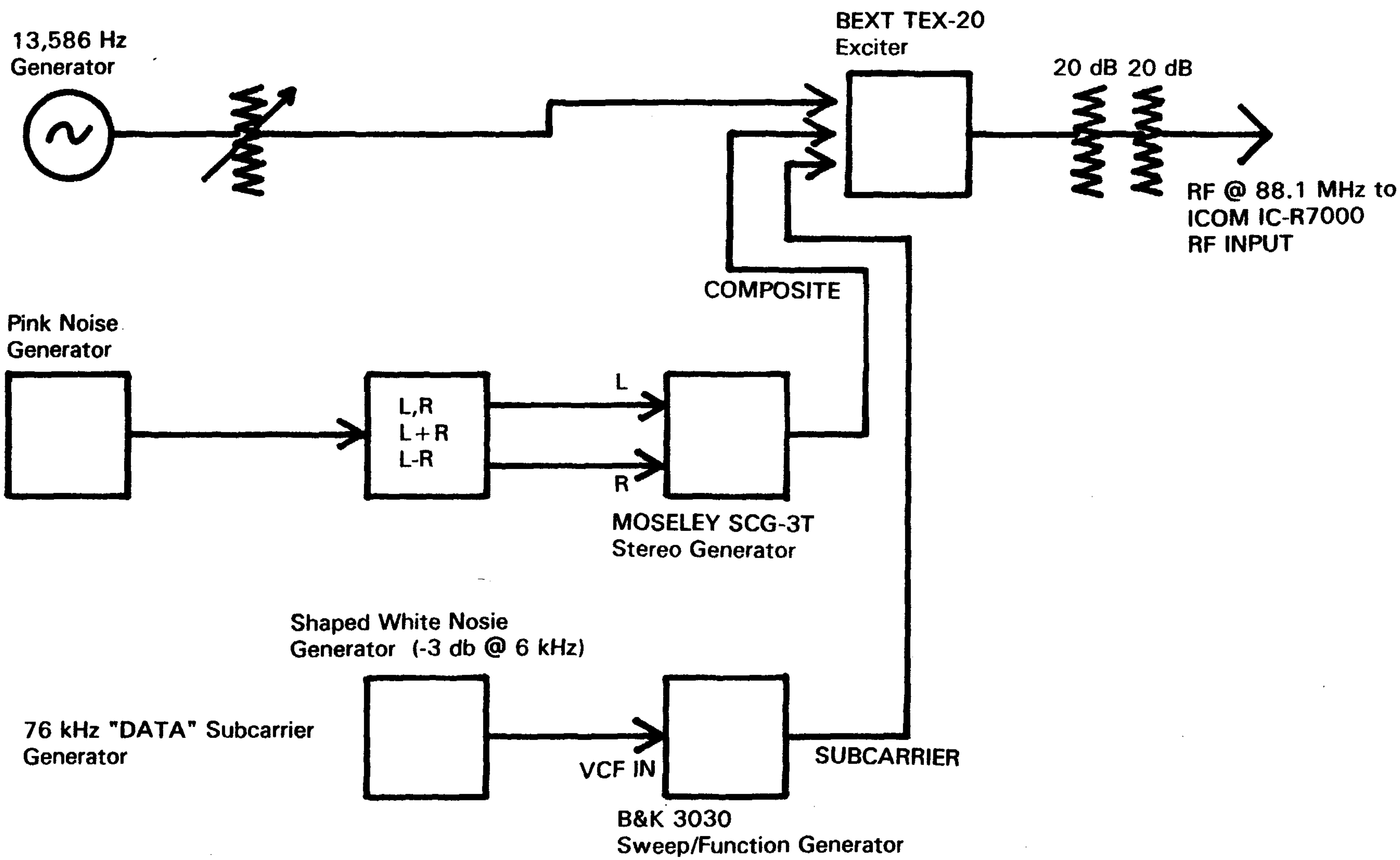
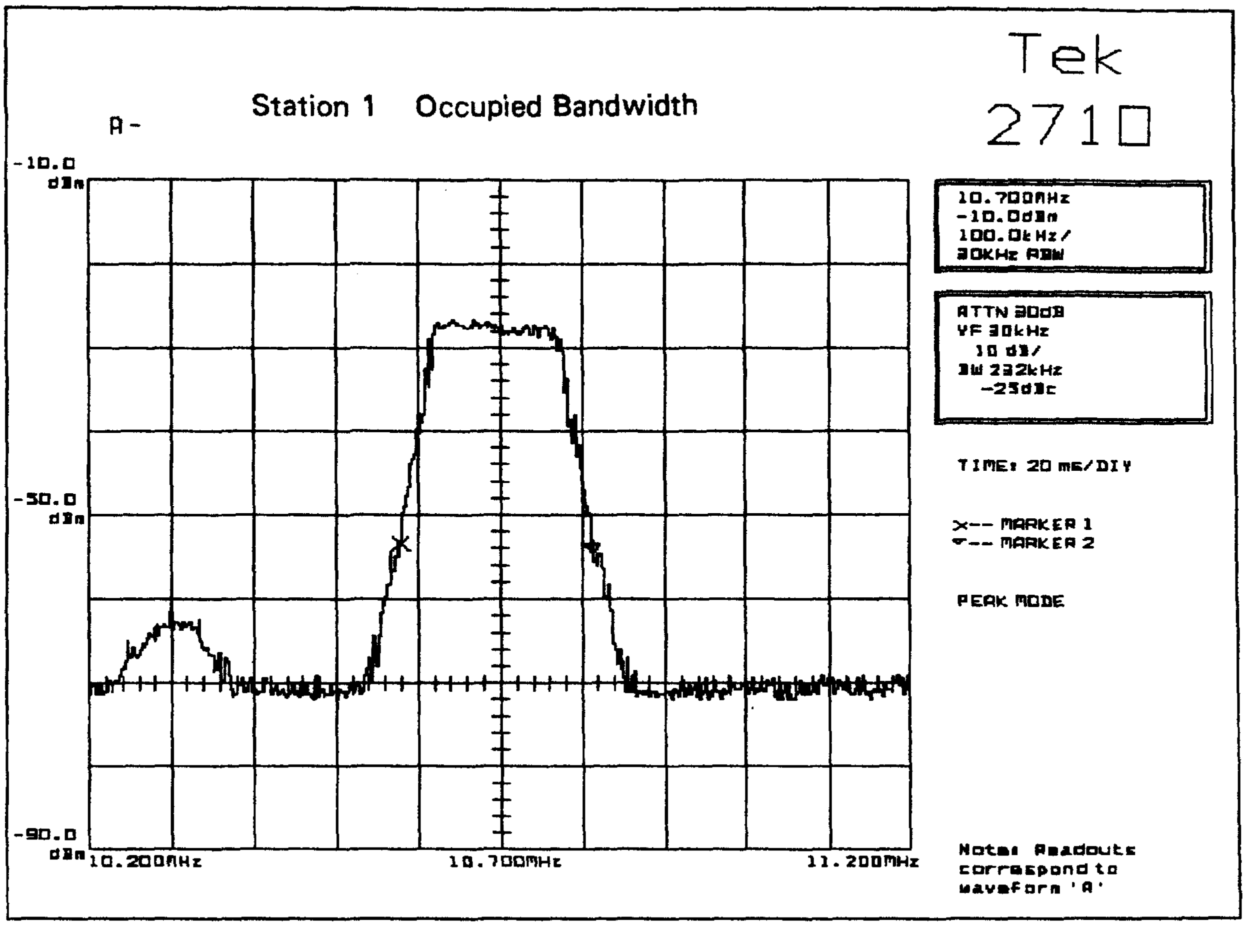
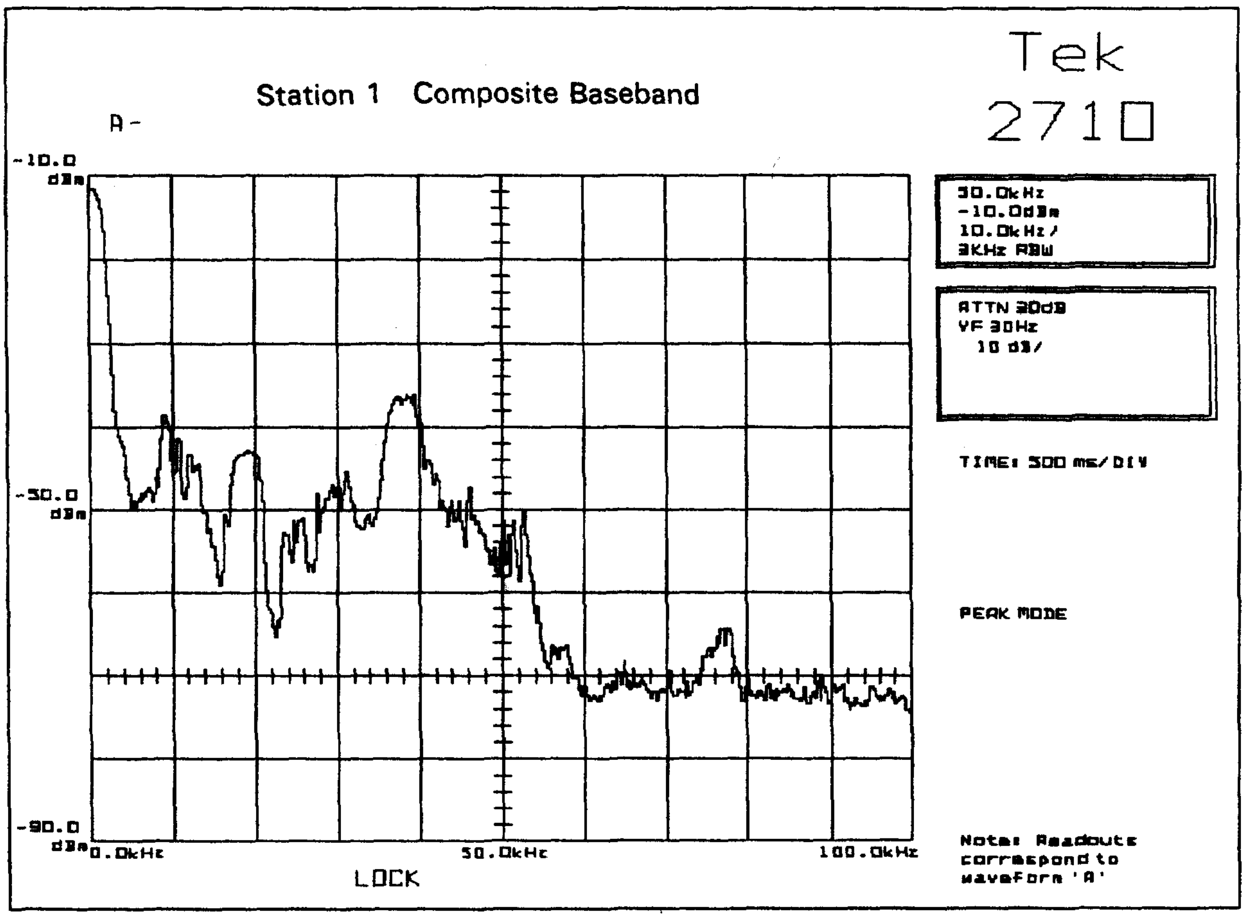


FIGURE 3 EXPERIMENTAL SETUP

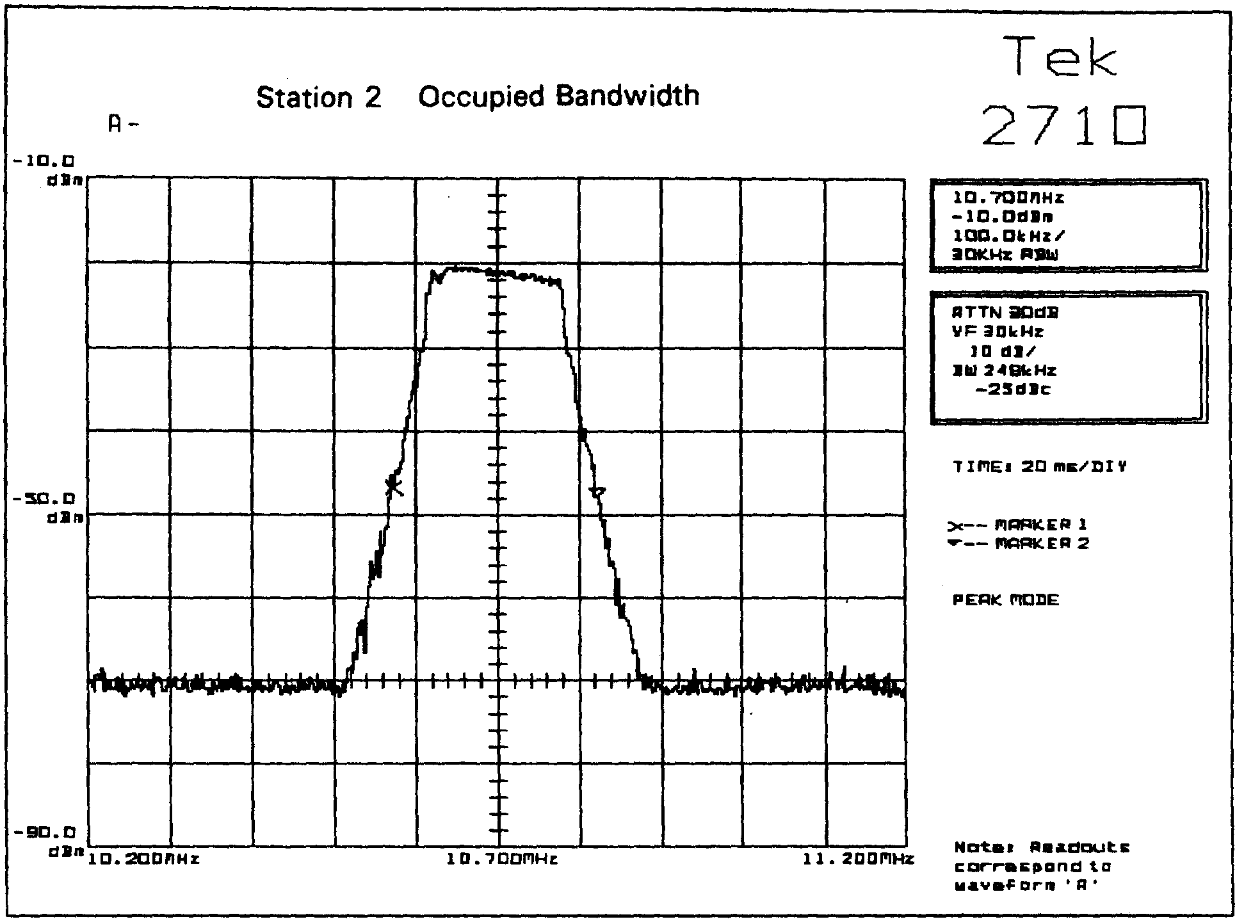
FOR OCCUPIED BANDWIDTH EXPERIMENT
Response to NOI 93-225
William F. Ruck, Jr. Broadcast Engineer

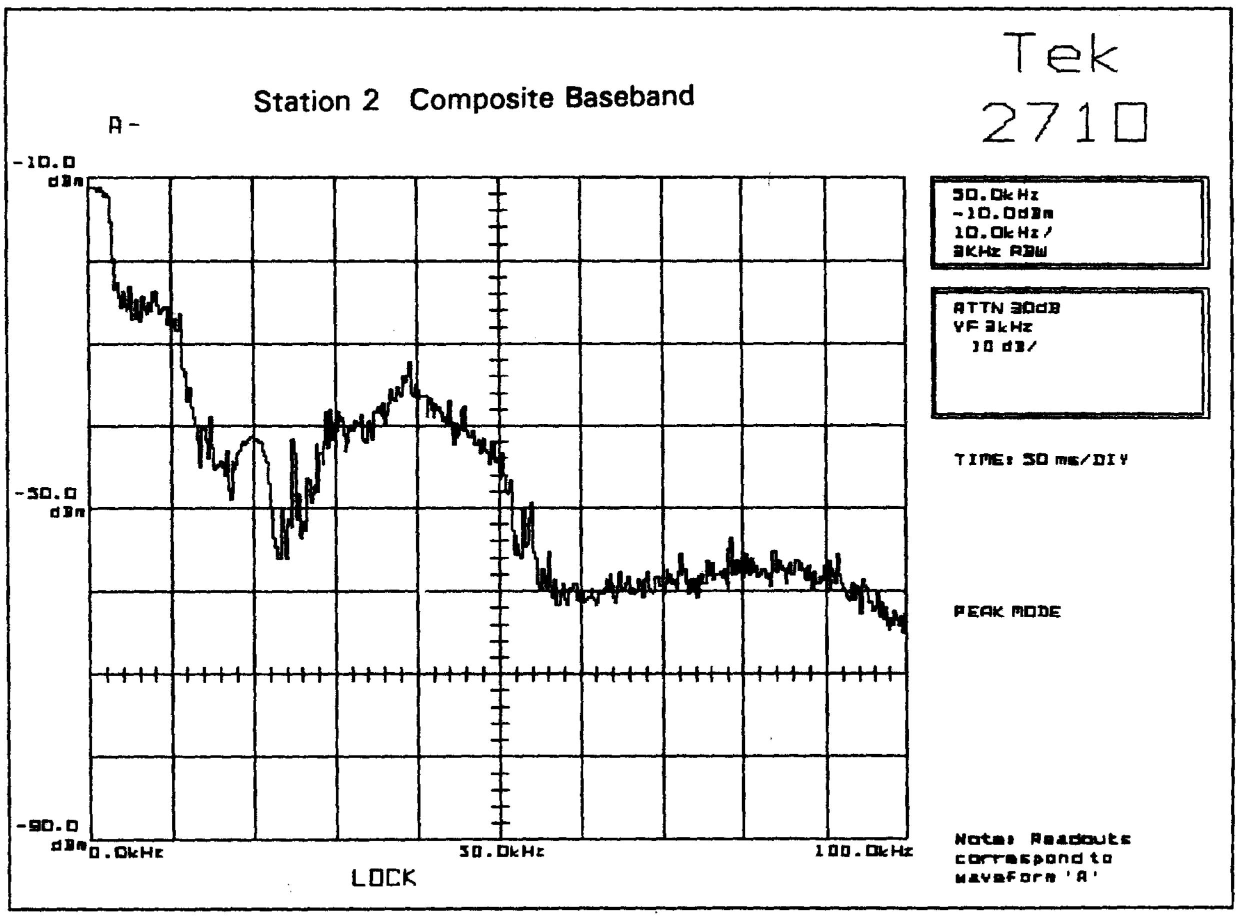


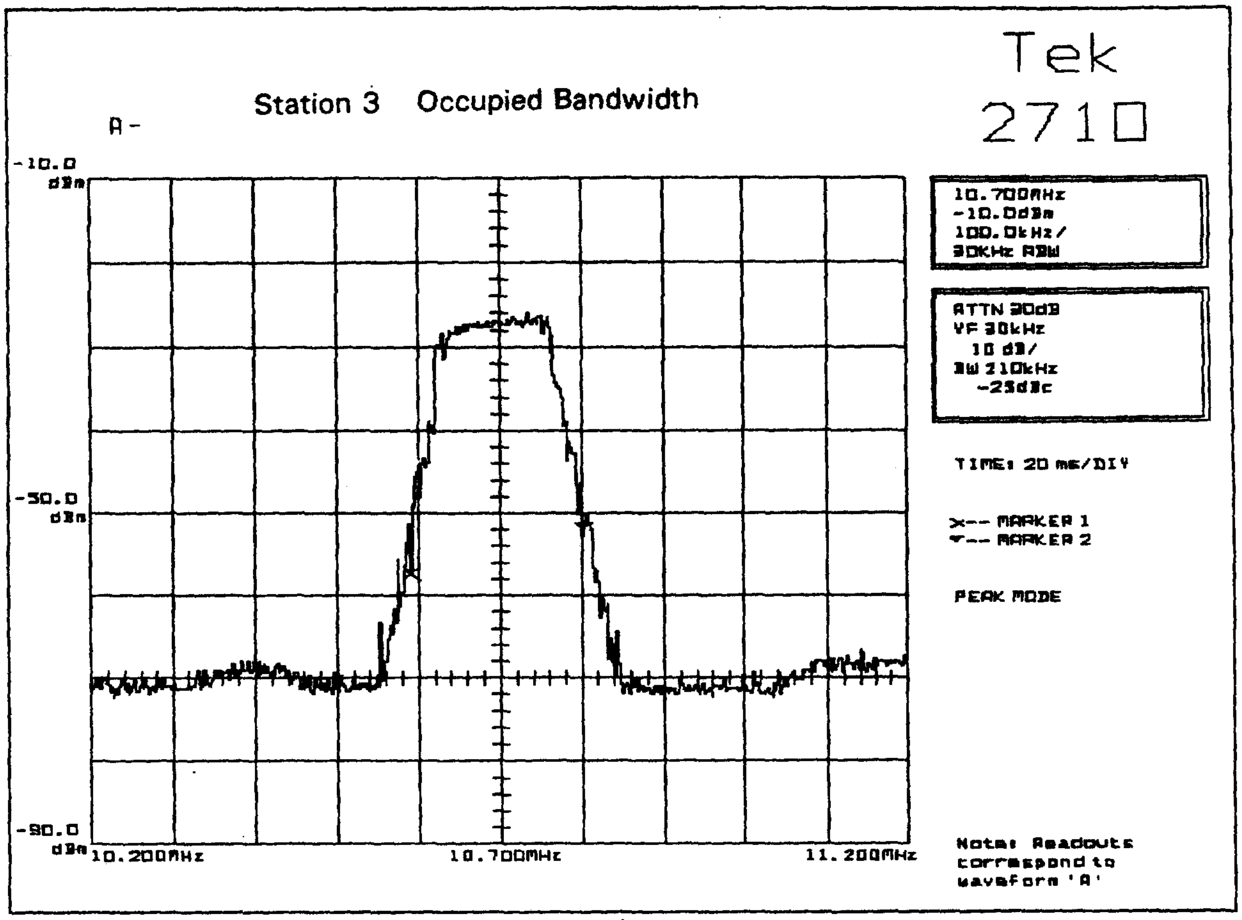
Station 1 Occupied Bandwidth
A-
Tek 2710
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 232kHz
-25dBc
TIME: 20 ms/DIV
x-- MARKER 1
--- MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

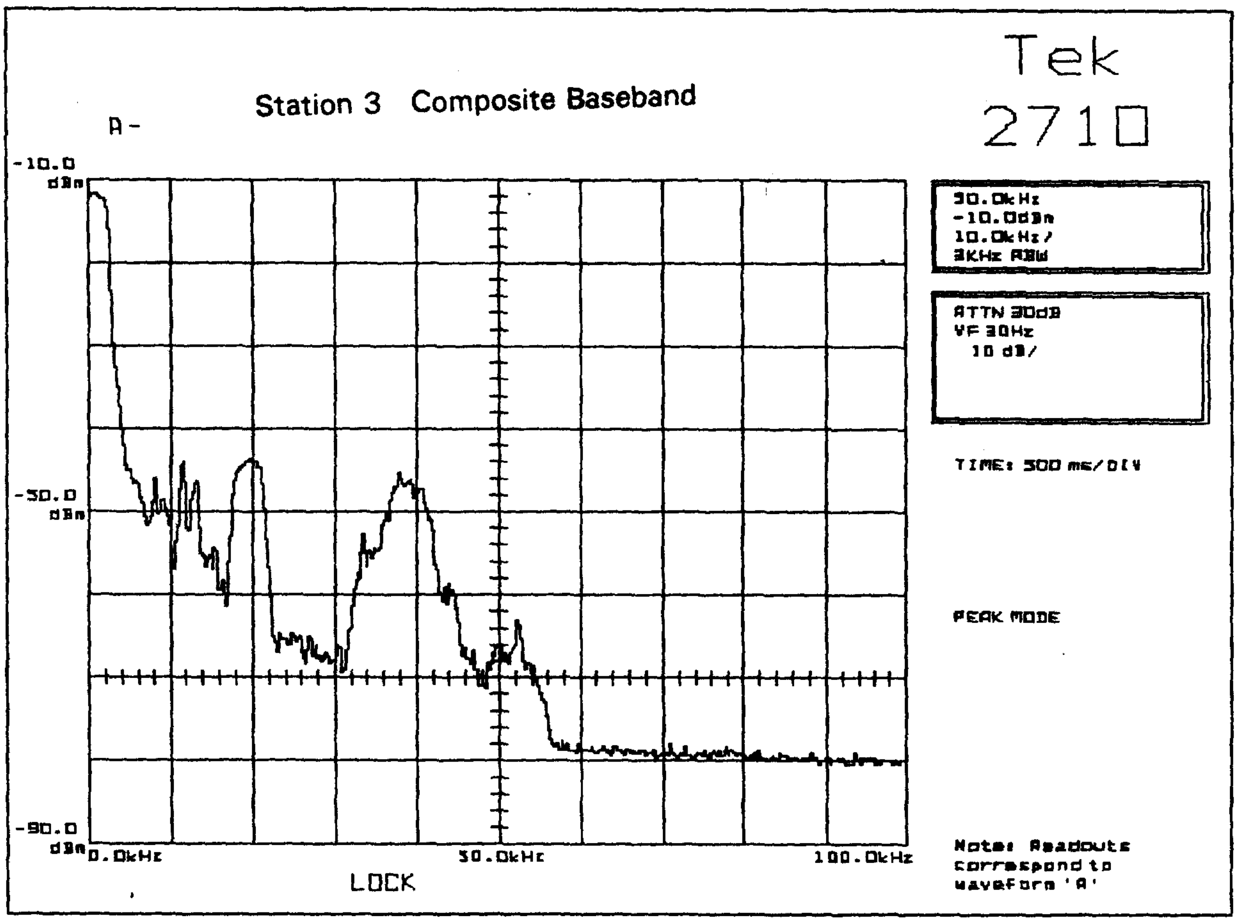


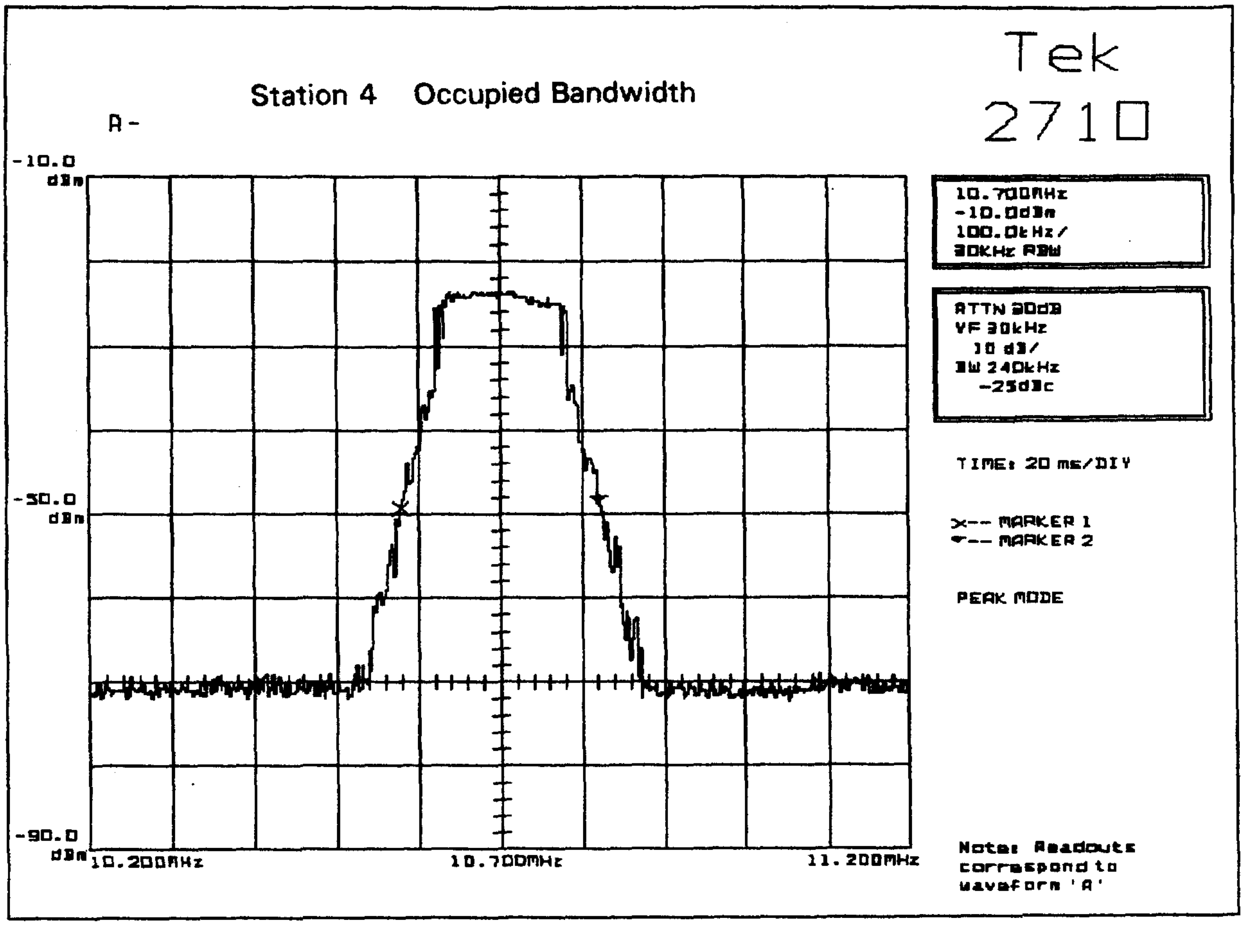
Station 1 Composite Baseband
A-
Tek 2710
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'

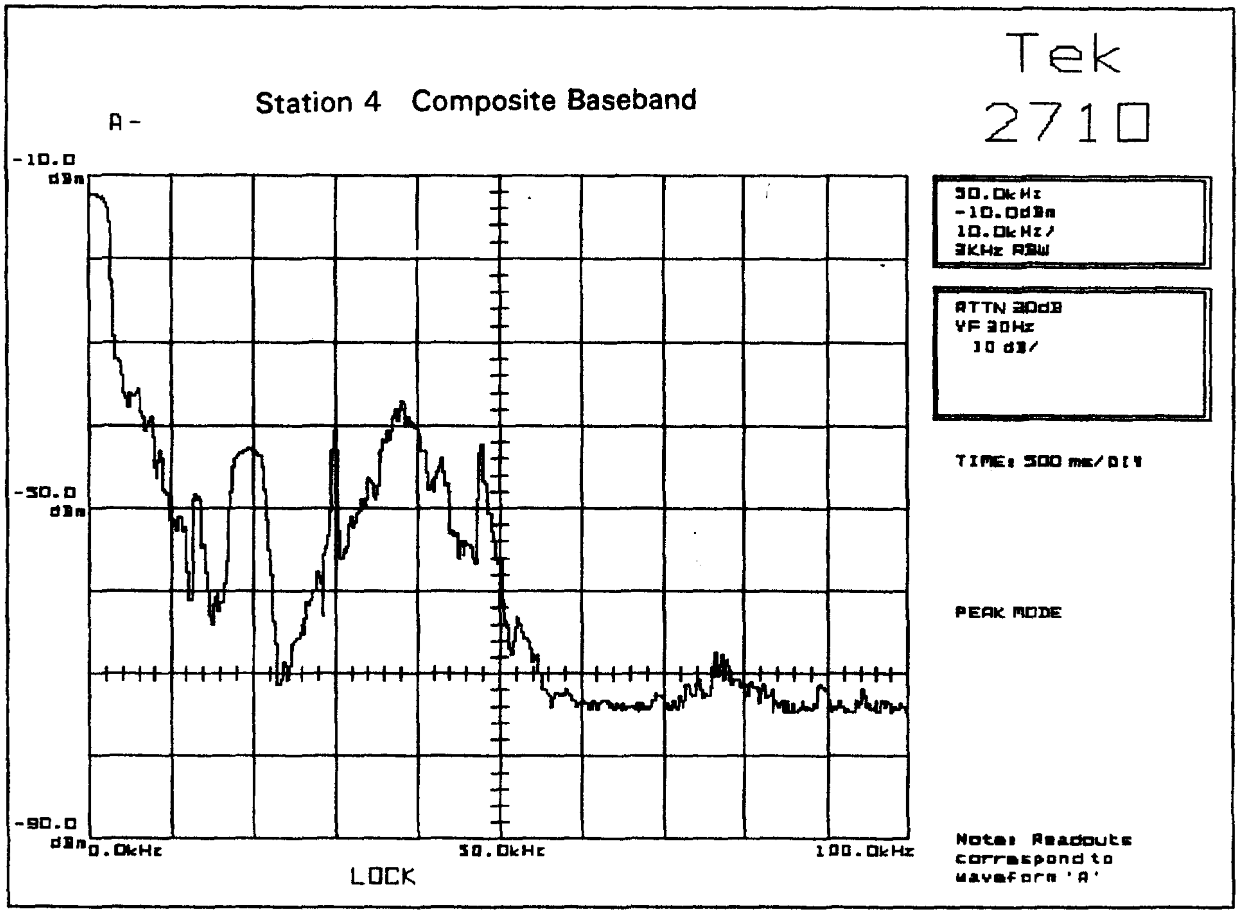

Station 2 Occupied Bandwidth
Tek 2710
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 248kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

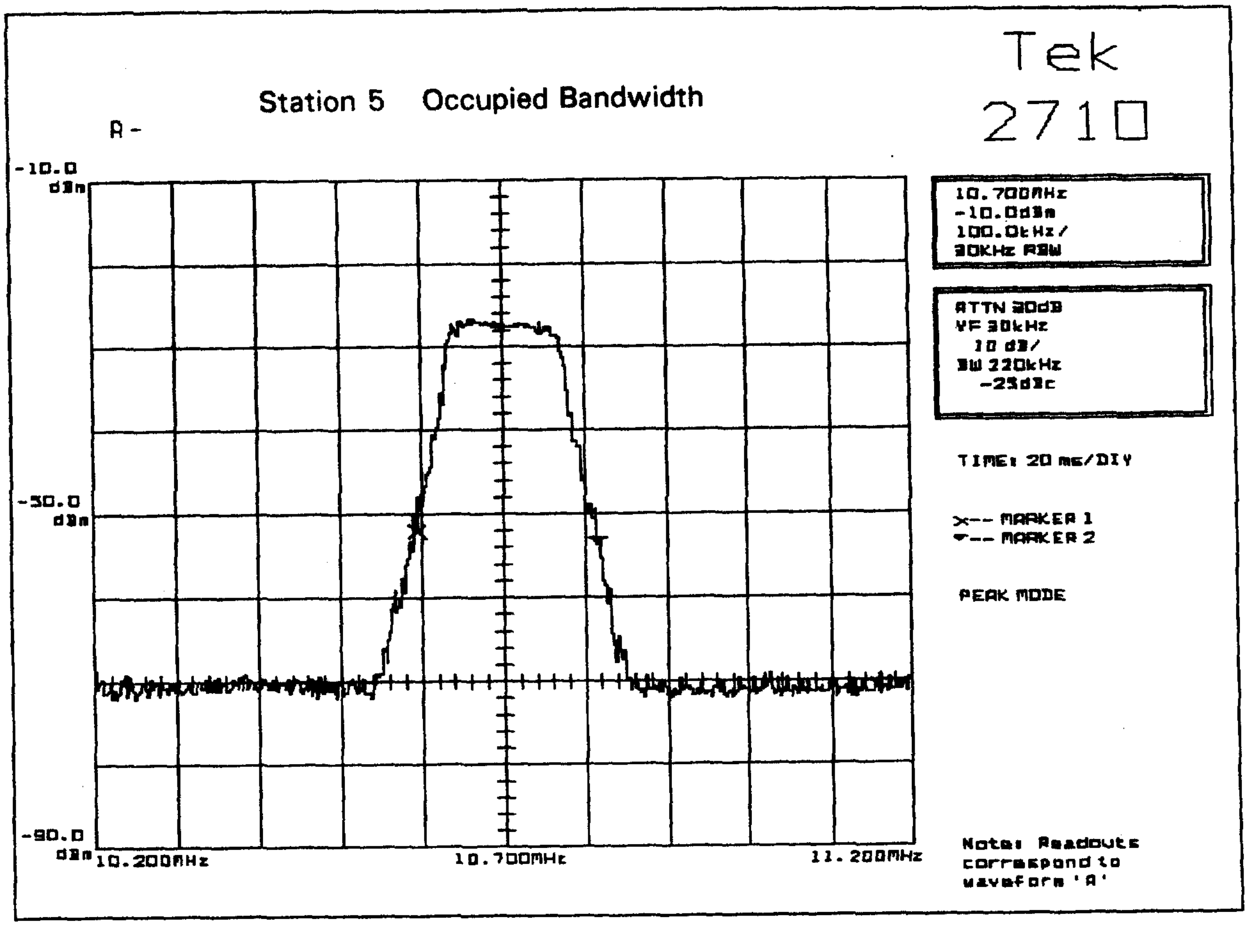

Station 2 Composite Baseband
Tek 2710
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 3kHz
10 dB/
TIME: 50 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'

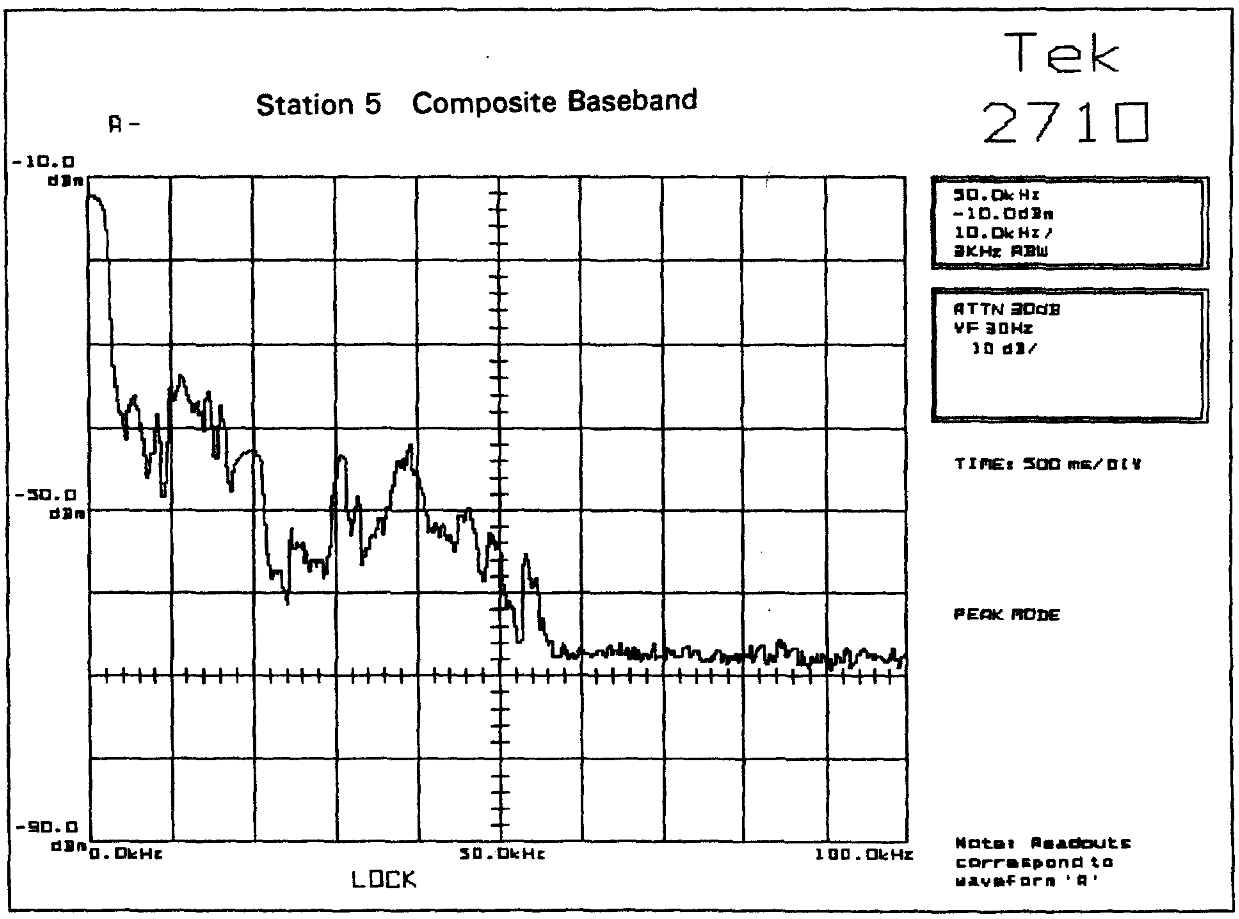

Tek
2710
Station 3 Occupied Bandwidth
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 210kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

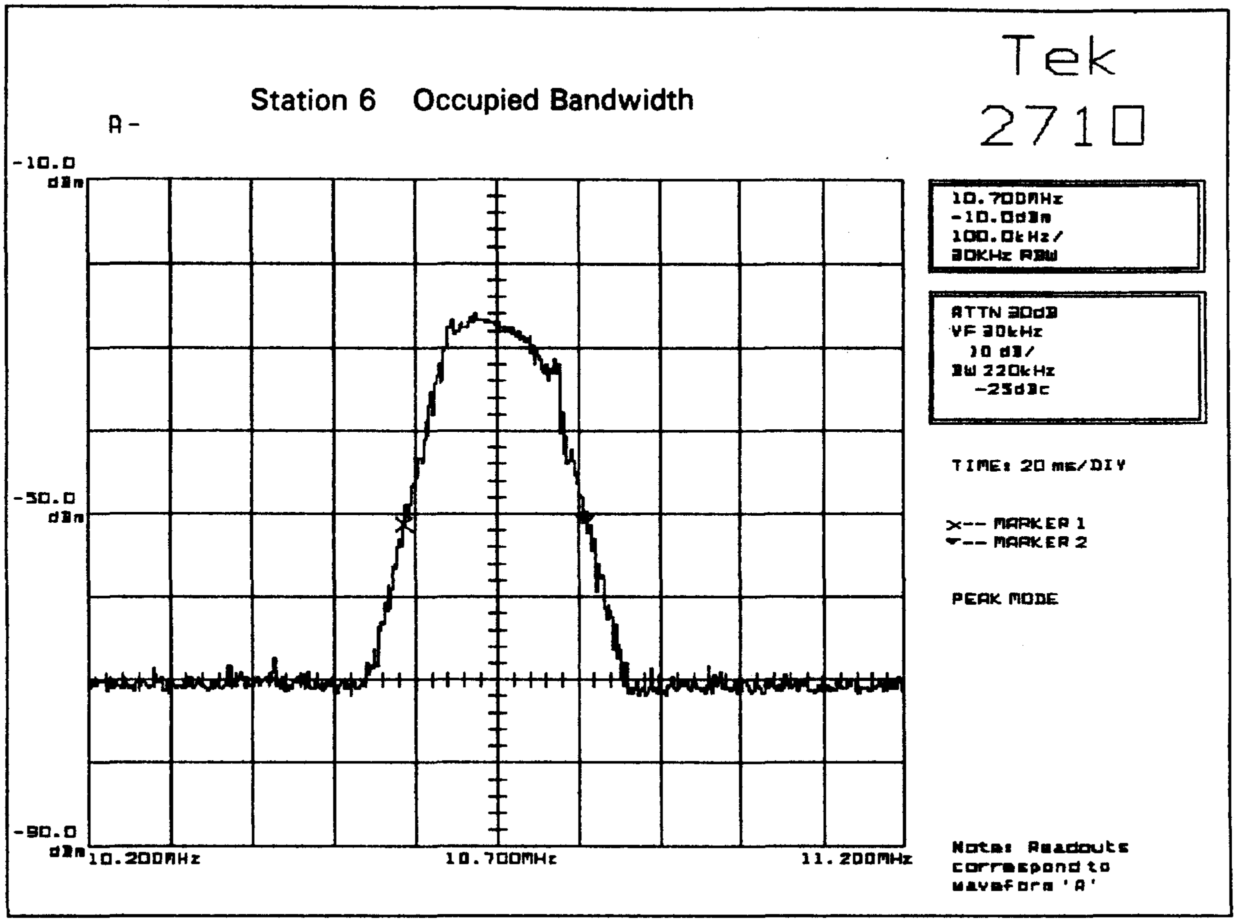

Tek
2710
Station 3 Composite Baseband
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'


Station 4 Occupied Bandwidth
A-
Tek
2710
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 240kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

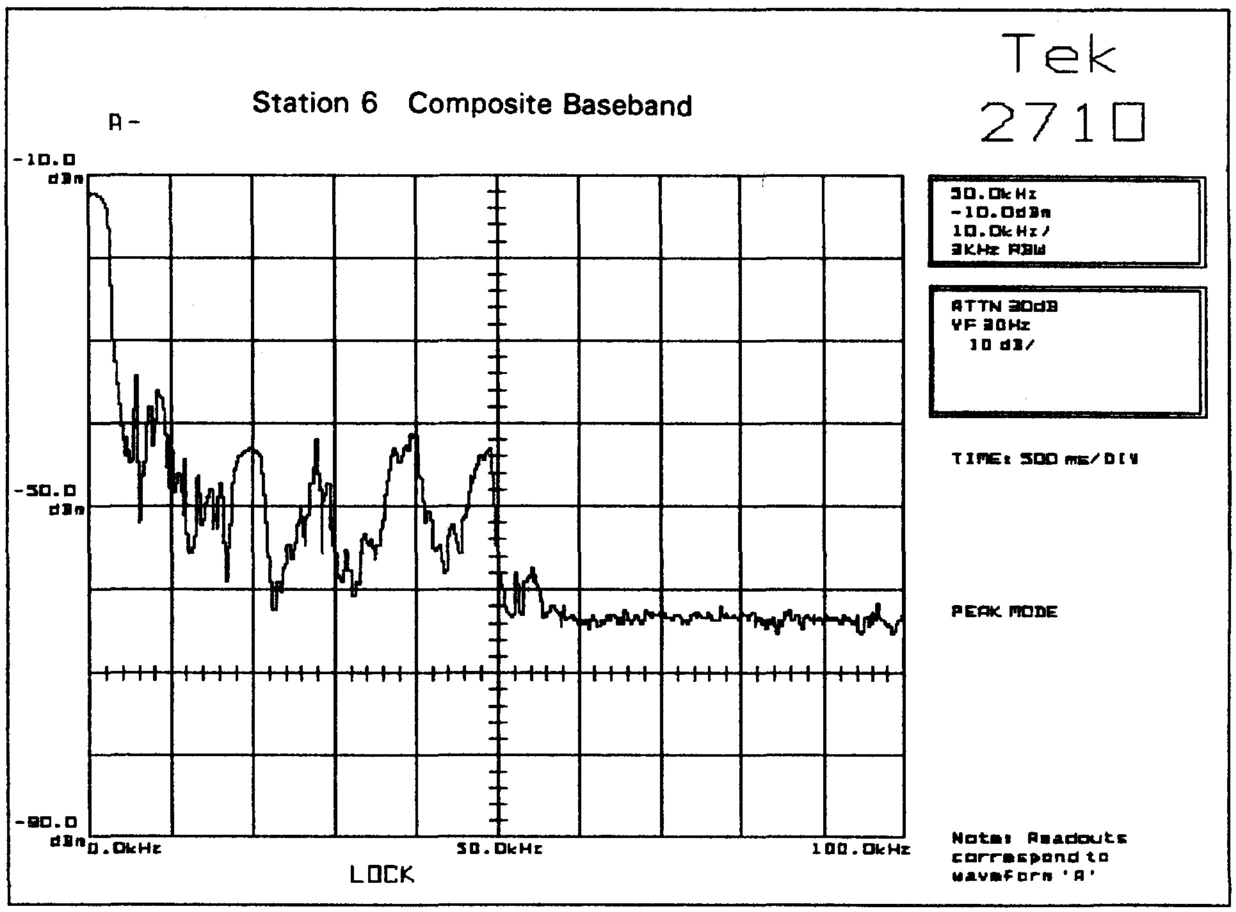

Station 4 Composite Baseband
A-
Tek
2710
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'


Tek
2710
Station 5 Occupied Bandwidth
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 220kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

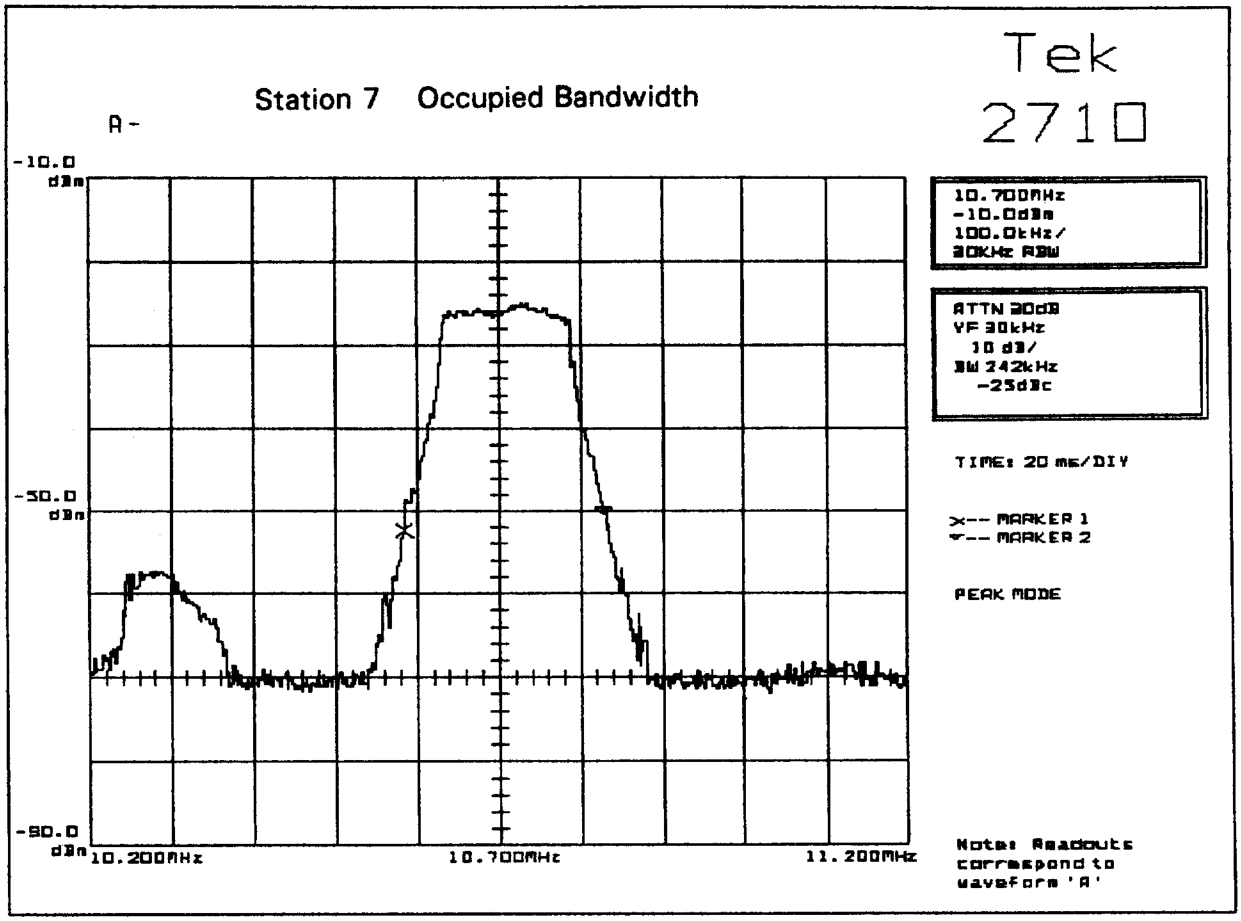

Tek
2710
Station 5 Composite Baseband
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'

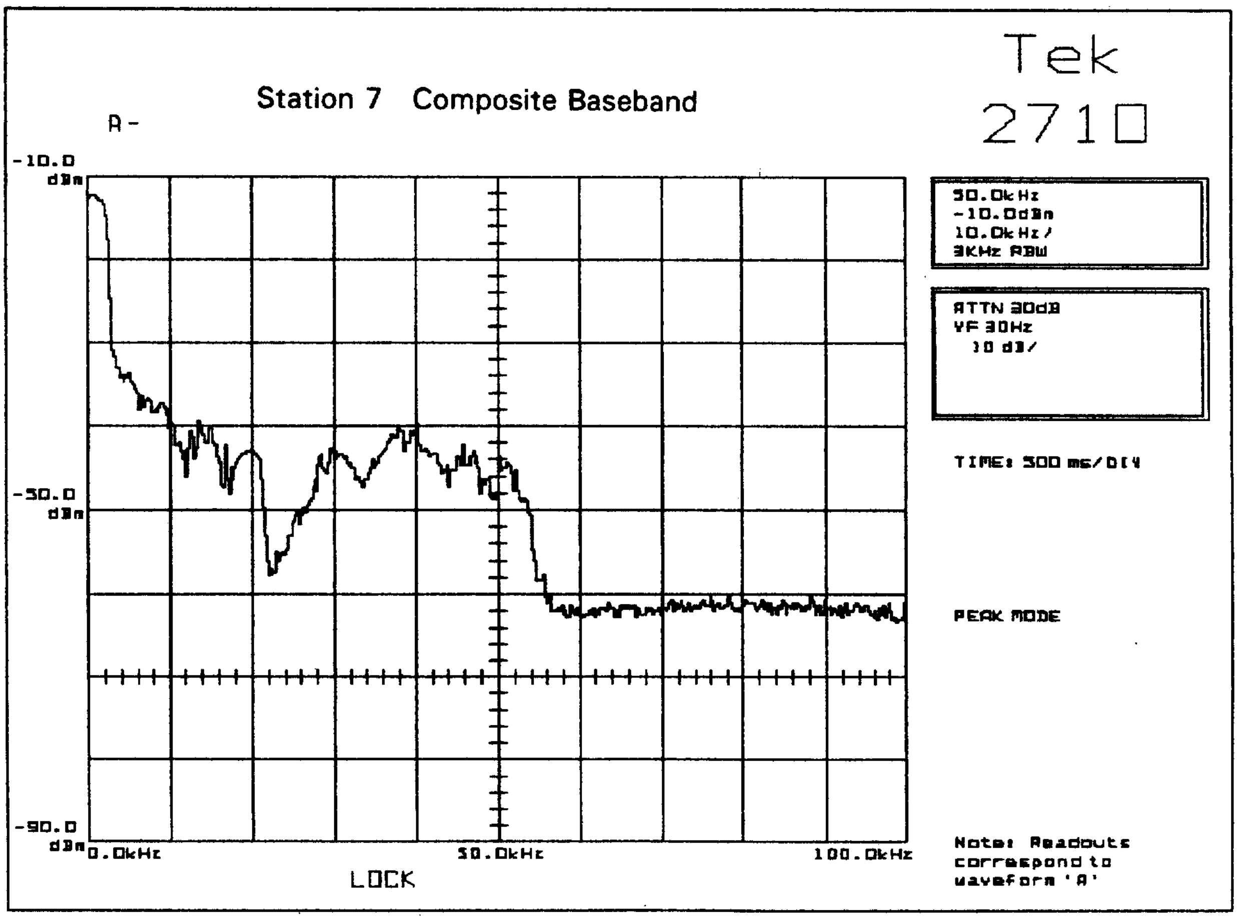


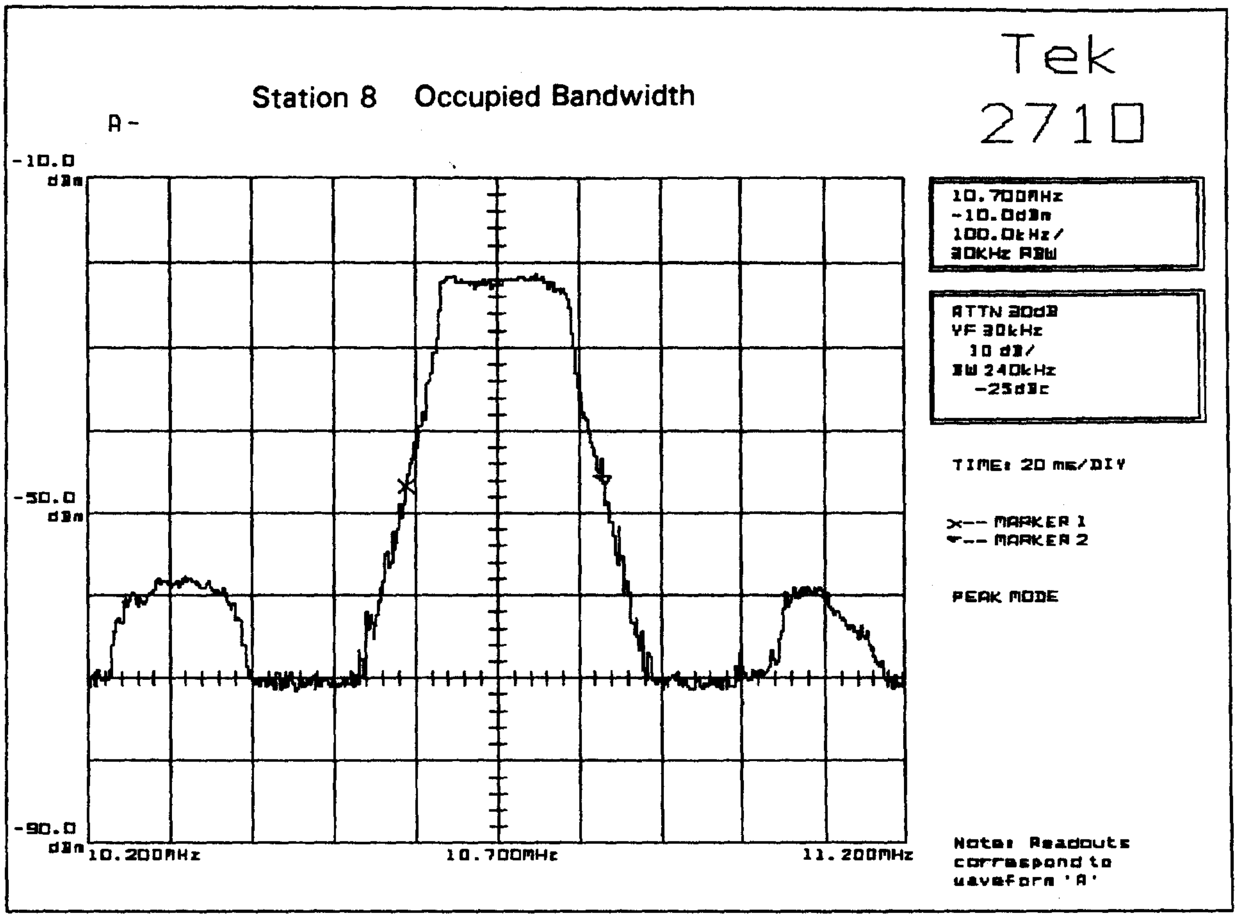
Station 6 Occupied Bandwidth

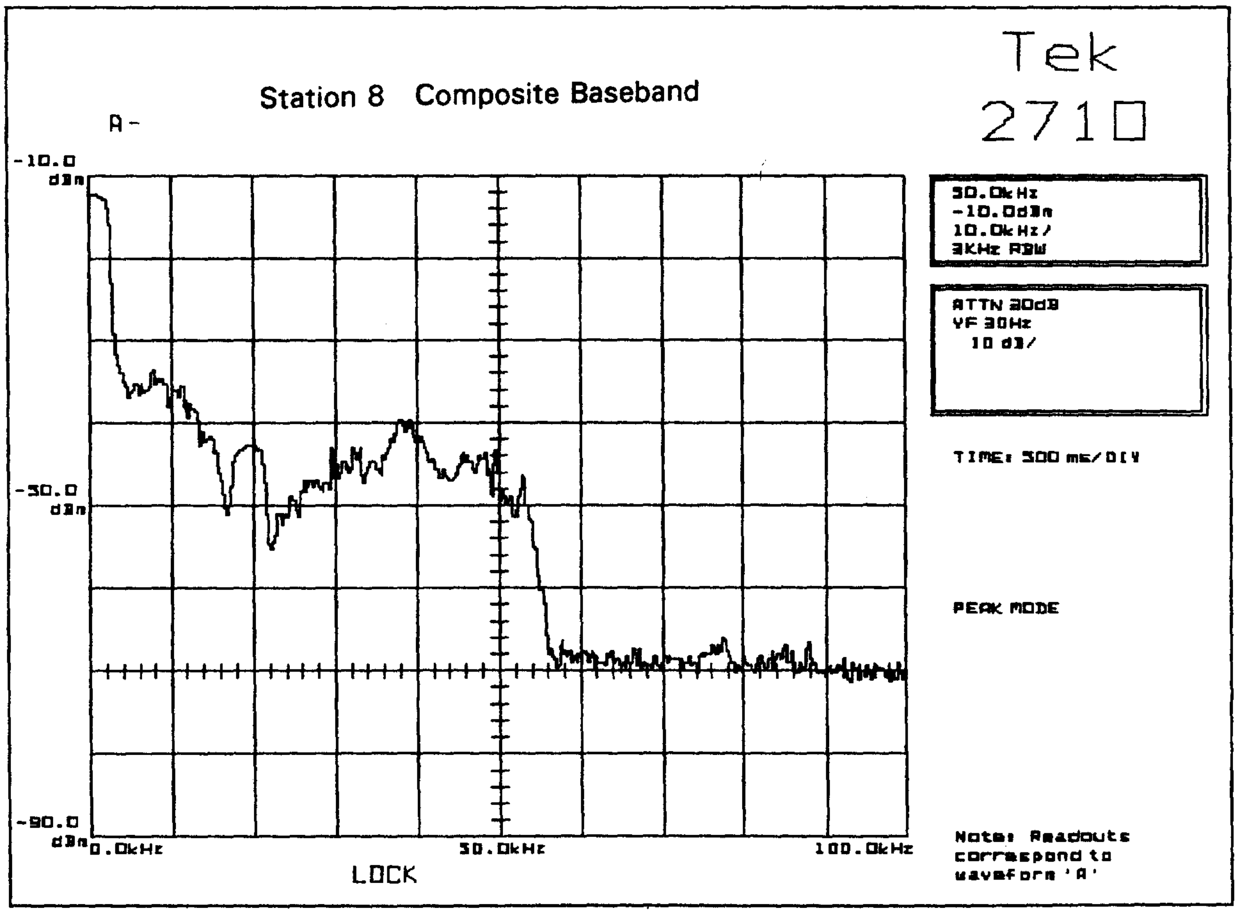


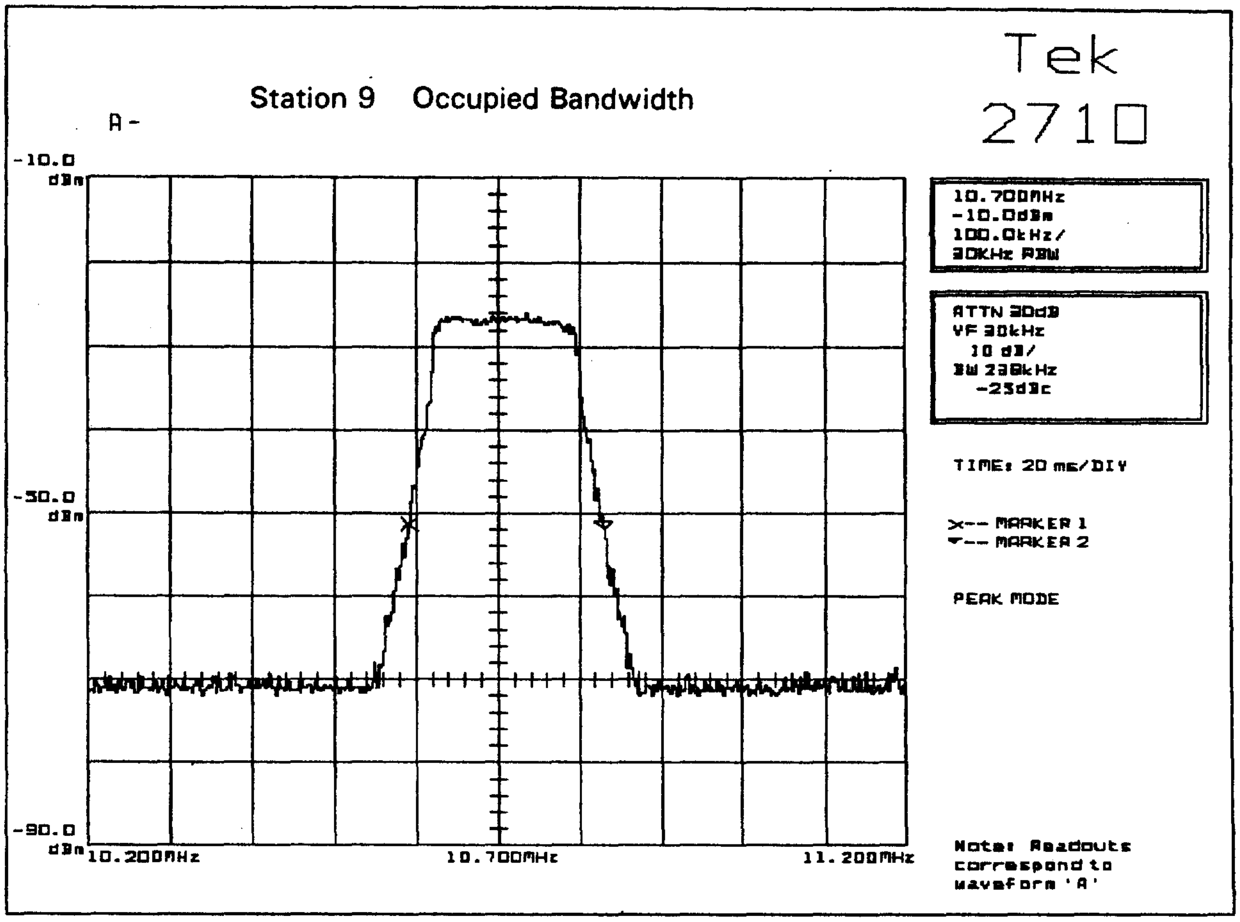
Station 6 Composite Baseband


Station 7 Occupied Bandwidth
Tek 2710
A -
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 242kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

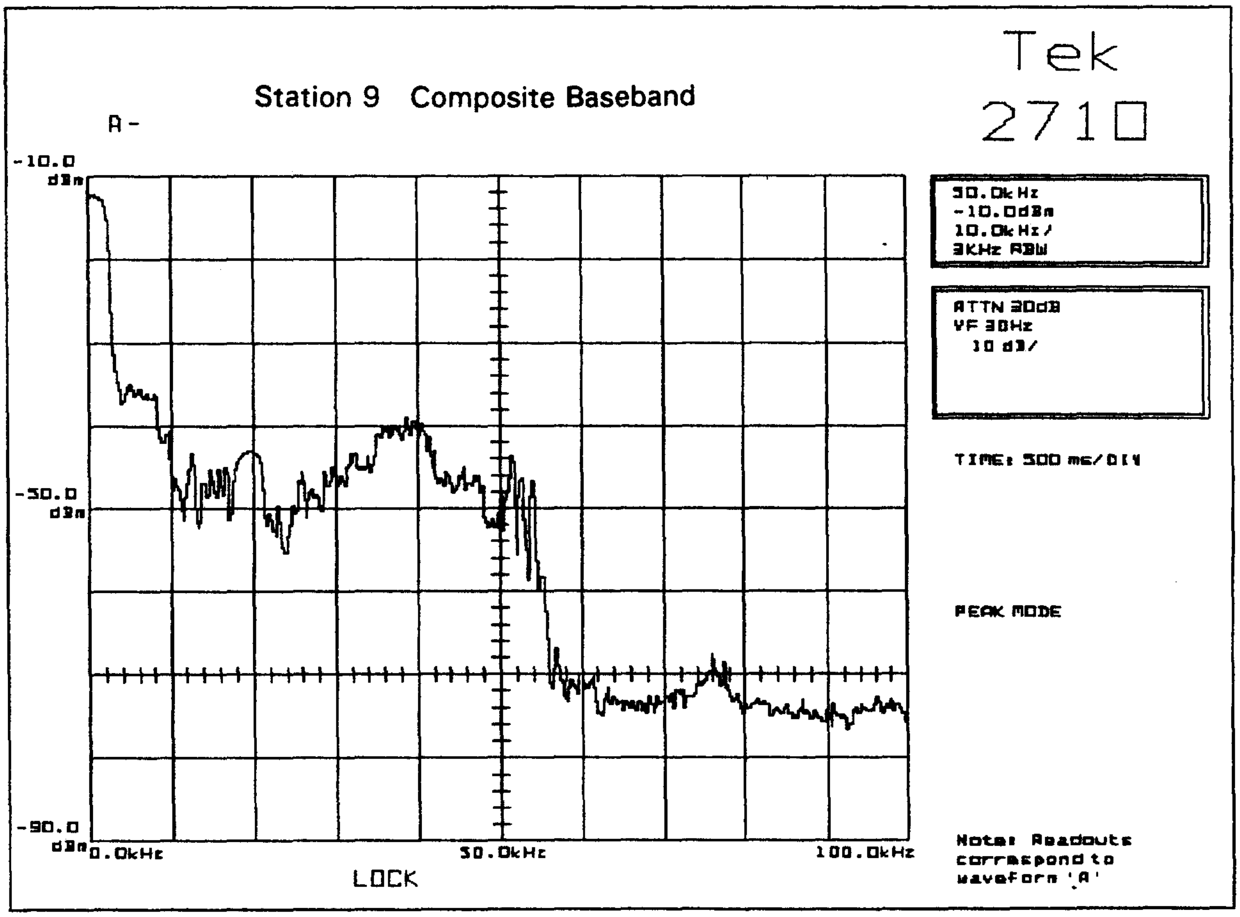

Station 7 Composite Baseband
Tek 2710
A -
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'


Tek 2710
Station 8 Occupied Bandwidth
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 240kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'

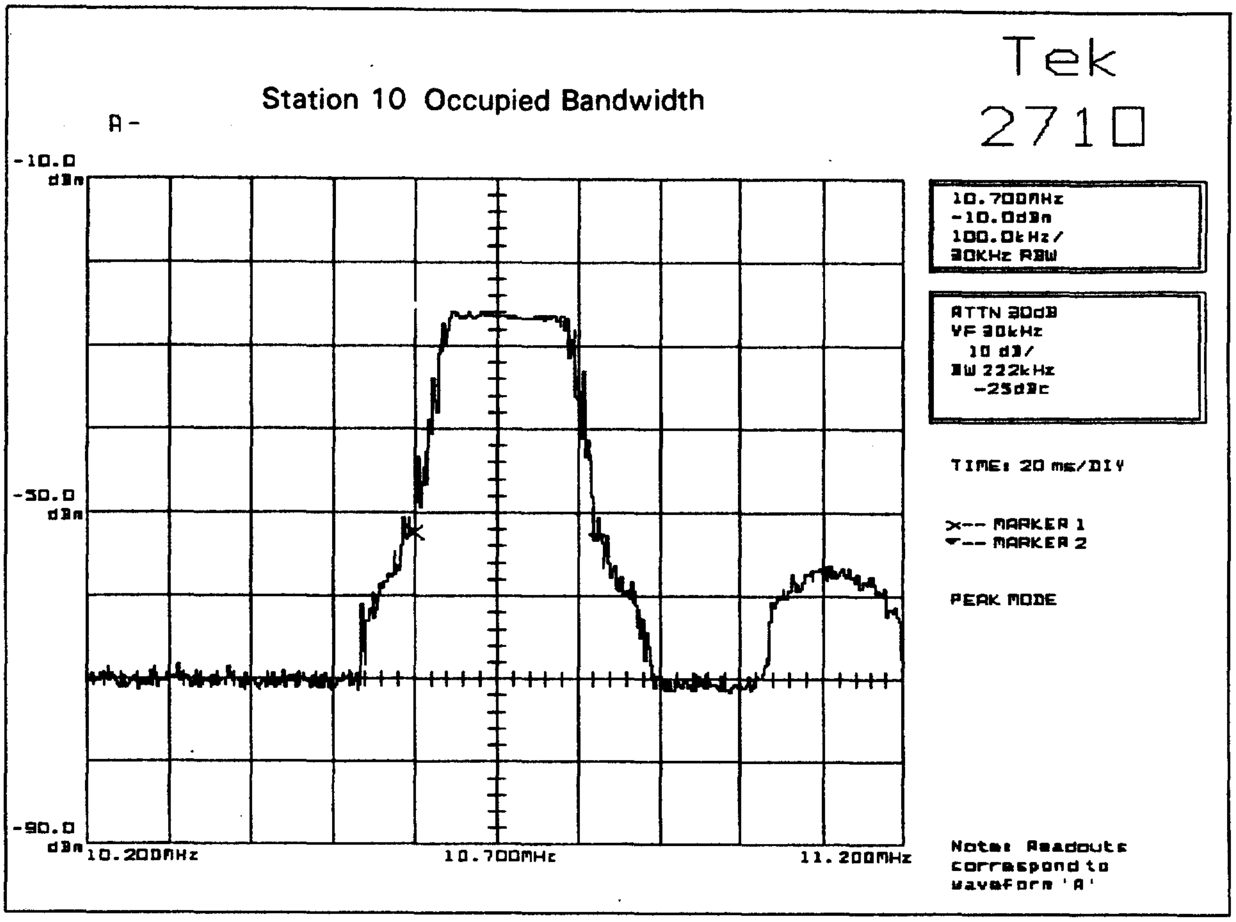

Tek 2710
Station 8 Composite Baseband
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'

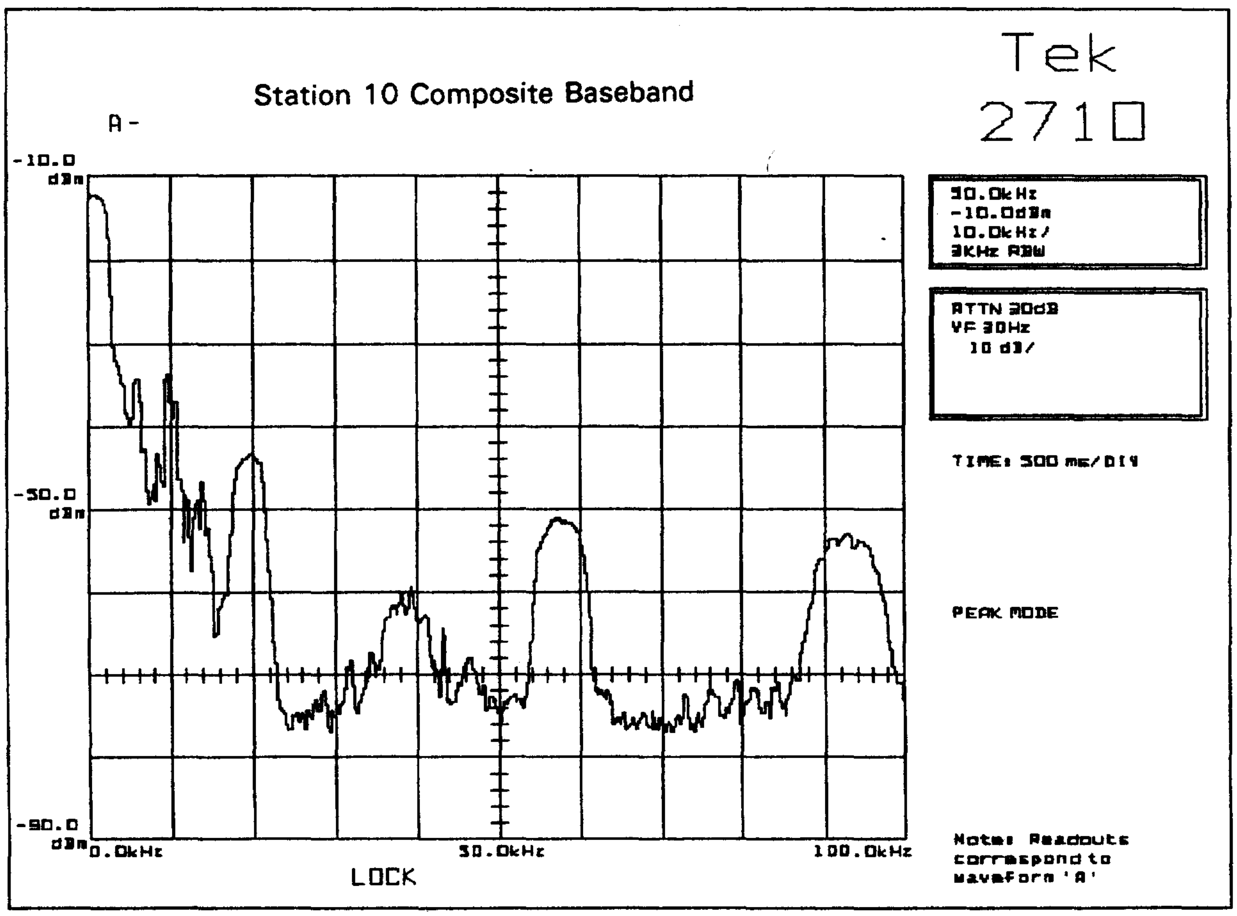


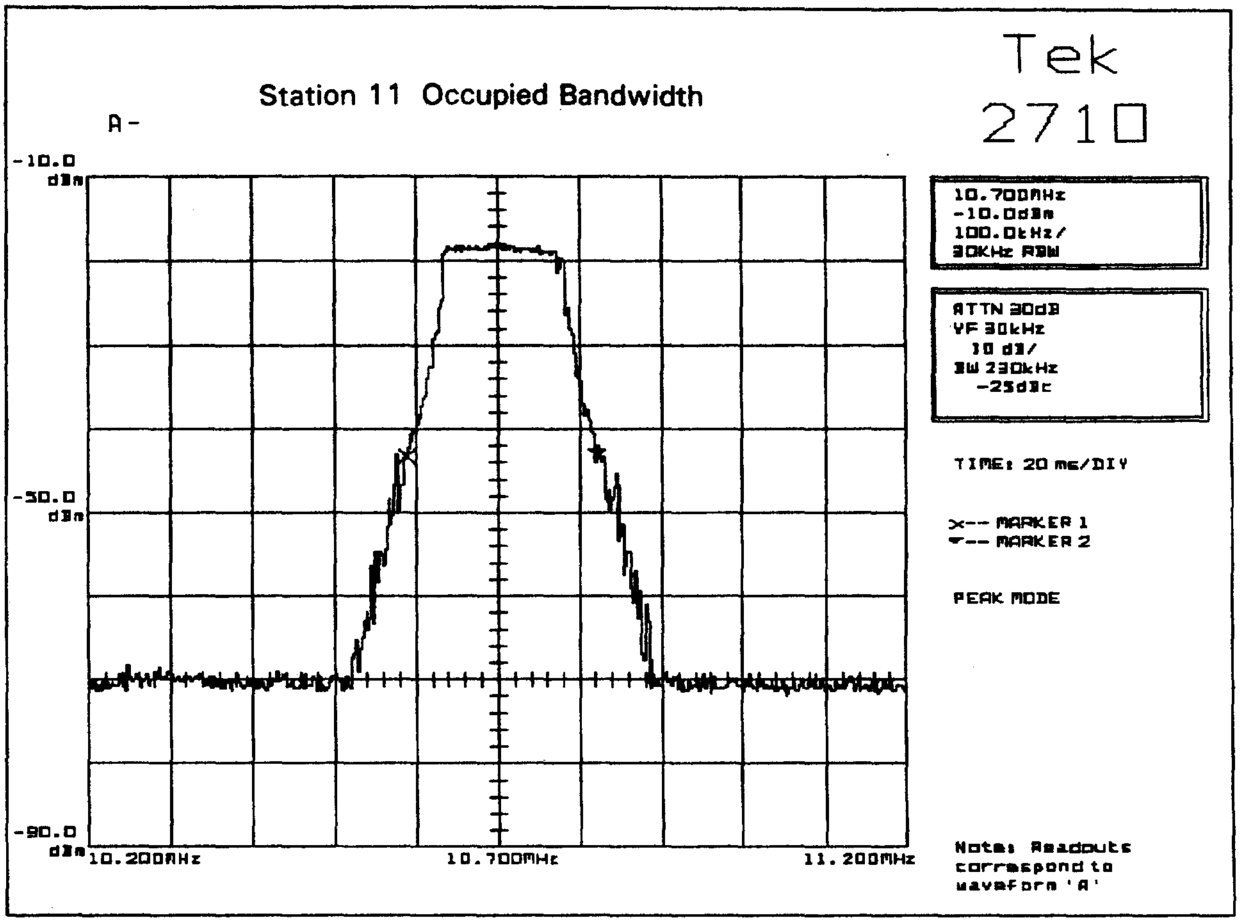
Tek
2710
Station 9 Occupied Bandwidth
A-
-10.0
dBm
-50.0
dBm
-90.0
dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 238kHz
-25dBc
TIME: 20 ms/DIV
X-- MARKER 1
▼-- MARKER 2
PEAK MODE
Note: Readouts
correspond to
waveform 'A'

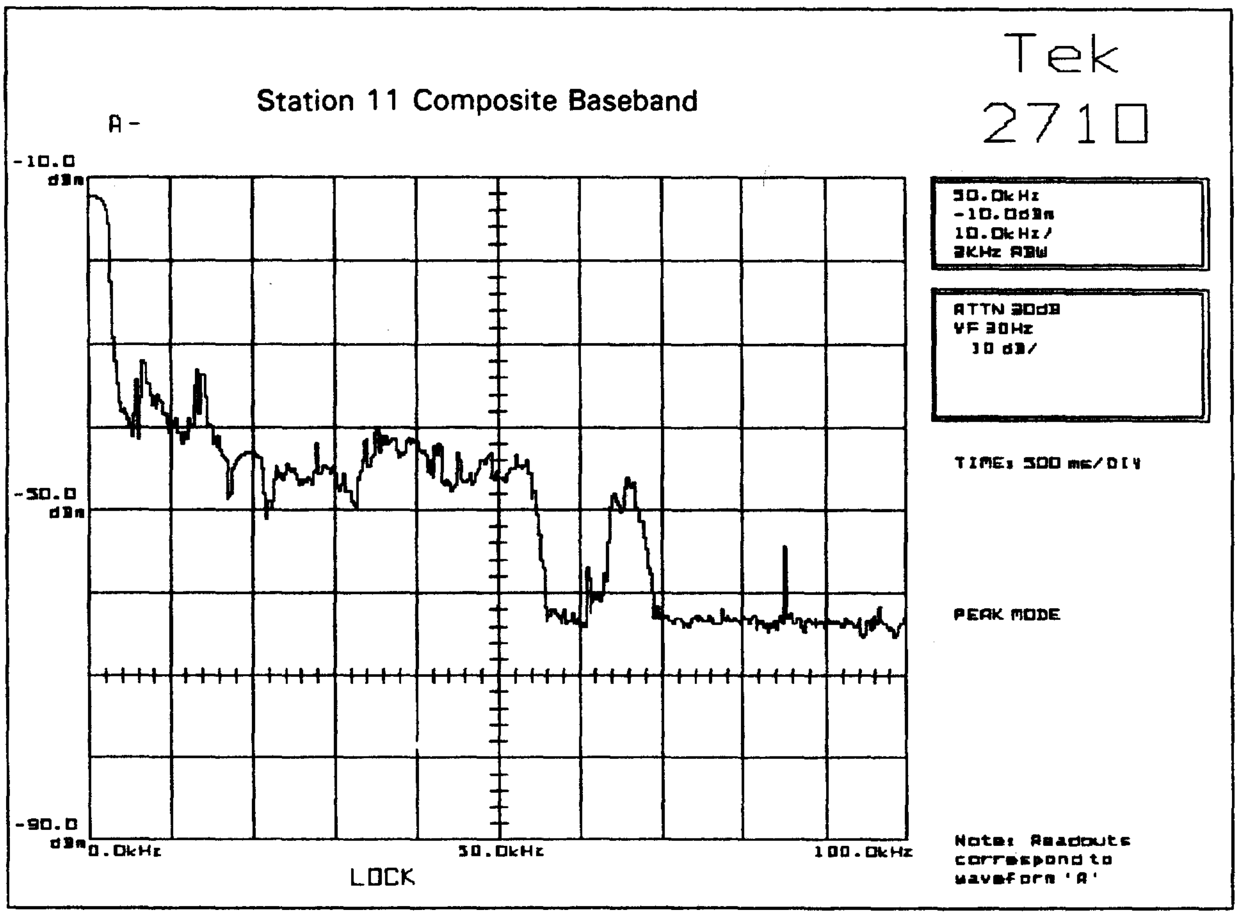


Tek
2710
Station 9 Composite Baseband
A-
-10.0
dBm
-50.0
dBm
-90.0
dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts
correspond to
waveform 'A'


Station 10 Occupied Bandwidth
Tek
2710
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 222kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'


Station 10 Composite Baseband
Tek
2710
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'


Station 11 Occupied Bandwidth
Tek
2710
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
10.200MHz
10.700MHz
11.200MHz
10.700MHz
-10.0dBm
100.0kHz/
30KHz RBW
ATTN 30dB
VF 30kHz
10 dB/
BW 230kHz
-25dBc
TIME: 20 ms/DIV
MARKER 1
MARKER 2
PEAK MODE
Note: Readouts correspond to waveform 'A'


Station 11 Composite Baseband
Tek
2710
A-
-10.0 dBm
-50.0 dBm
-90.0 dBm
0.0kHz
50.0kHz
100.0kHz
LOCK
50.0kHz
-10.0dBm
10.0kHz/
3KHz RBW
ATTN 30dB
VF 30Hz
10 dB/
TIME: 500 ms/DIV
PEAK MODE
Note: Readouts correspond to waveform 'A'